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Proceedings of the NASA Aerospace Technology Symposium 2002

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Aerospace Technology Symposium 2002

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Leo Little (AL)	Astrobiology; Remote Sensing
Mike Odell (ID)	Idaho Space Grant Education Outreach Opportunities; Pre-service Teacher Project; NOVA Workshops
Michaela Schaaf (NE)	Implementation of General Aviation Security
Don Scott (SC)	Small Aircraft Transportation System Development
Fred Striz (OK)	Aviation World's Fair 2003
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**Aerospace Technology Symposium
Las Cruces/ White Sands Test Facility
March 3-5, 2002**

Sunday, March 3

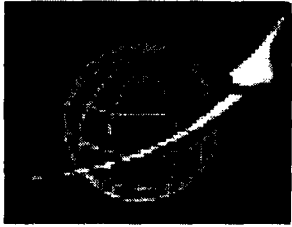
6:30 p.m. Working dinner/Roundtable presentations begin, Mesilla Room-Holiday Inn

Monday, March 4

7:15 a.m. Meet in Holiday Inn lobby
7:30 a.m. Bus departs (boxed breakfast included)
8:15 a.m. Arrival at White Sands Test Facility. Bring photo id for access.
8:45 a.m. Welcome, Joe Fries - NASA White Sands Test Facility Manager
"White Sands Test Facility Overview"
9:30 a.m. "NASA Student and University Programs"
"WSTF Education Outreach Programs"
"Technology Outreach Program - Florida, Texas, New York, NM"
Pleddie Baker - WSTF Technology and Education Outreach
10:00 a.m. Break (The NASA Aeronautics Blueprint video will be shown)
10:20 a.m. "Success of Student and Faculty Employee Programs,"
Dr. Harry Johnson - Chief of Laboratories Office
Vern Brown - Chief of Administration Office
10:40 a.m. "How Students/Faculty can integrate into Honeywell,"
Mark Leifesté - Honeywell Program Manager
11:00 a.m. "Unmanned Autonomous Vehicles"
Bill Gutman - Physical Science Laboratory
11:30 a.m. Lunch - Back room of Cafeteria
12:30 p.m. Tour of WSTF Laboratories
2:00 p.m. Tour Propulsion Test Area
3:00 p.m. Bus leaves for White Sands National Monument
3:45 p.m. Tour of White Sands Monument (& White Sands Missile Range
Museum, time permitting)
4:45 p.m. Board bus for return to Holiday Inn
5:30 p.m. Break
7:00 p.m. Working dinner/Conclusion of roundtable presentations,
Mesilla Room- Holiday Inn

Tuesday, March 5

8:00 a.m. Working breakfast, Border Café & Cantina- Holiday Inn
Items of business:
- NASA's Aeronautics Blueprint (presented by Brent Bowen on
behalf of Bruce Holmes)
- Future Symposia/Sponsorships: Aviation World's Fair, April
2003 (tentative co-sponsor with LaRC); Langley Research
Center, December 15-16, 2003 to precede Centennial of Flight
Celebration at Kitty Hawk
- Journal of Air Transportation Update
- WG Considerations: Election for Chair to be held at DC
Space Grant Directors Meeting, March 20-24; Ongoing
collaboration/opportunities with ASA, SATS, Spaceport
Initiative
10:00 a.m. Symposium conclusion



AEROSPACE TECHNOLOGY (AERONAUTICS)

LAS CRUCES/WHITE SANDS TEST FACILITY

MARCH 3-5, 2002

MINUTES

Sunday, March 3

6:30 p.m. Working dinner/roundtable presentations begin. Please see attendees list for roundtable presentation topics.

Monday, March 4

8:00 a.m. Arrival at White Sands Test Facility (WSTF)

8:30 a.m. Joe Fries, WSTF Manager, gave an welcome and overview. He also presented *Space Commercialization and Space Commission Offices*.

WSTF is a conglomeration of Johnson Space Center, NASA Headquarters, Army, Navy, Air Force, Department of Energy, Department of Defense, and Industry

WSTF mission includes:

- Propulsion system testing, spacecraft
- Materials/component testing

Spaceport construction is proposed for the future.

8:50 a.m. Pleddie Baker, WSTF Technology and Education Outreach Coordinator, discussed NASA student and university programs. He presented the *Role of Education Outreach and Counterparts at other Higher Education Institutions*.

Student opportunities at NASA pay less than industry. Undergraduates start at GS4; Graduates at GS7; Doctoral students range from GS9 to GS11 to start.

See: <http://education.jsc.nasa.gov/college/lpi.htm> and

<http://www.lpi.usra.edu/lpiintern.html>. Search for Project Access.

9:20 a.m. Harry Johnson, WS Chief of Laboratories Office, spoke about the WSTF/New Mexico Space Grant Student Employee Program. Success stories were given.

9:50 a.m. Vern Brown, Office Chief of Administration, discussed Education Outreach budgets. He too spoke of success stories.

10:30 a.m. Mark Leifesté, Honeywell Program Manager, presented *How Students/Faculty can Integrate into Honeywell*.

Juniors and seniors are employed as contract labor. They work over 20 hours per week and receive benefits, and seniority. There are also publishing opportunities.

11:00 a.m. Bill Gutman, of the WS Physical Science Laboratory, gave a presentation on Unmanned Autonomous Vehicles (UAVs).

UAVs are used for defense, agriculture, communities, law enforcement, aerial photography and mapping, emergency management and science/environmental research.

Design and certification standards, as well as airspace regulations must be taken into consideration.

The first UAV premiered in civil airspace in January of 2002.

Collaboration exists among the Department of Defense, Hawaii, Alaska, the National Oceanic and Atmospheric Administration (NOAA) and the WSTF.

- 11:30 a.m. Collaboration-building lunch
- 12:30 p.m. Tour of White Sands Test Facility Laboratories
- 3:45 p.m. Tour of White Sands Missile Range Museum and White Sands National Monument
- 4:45 p.m. Research presentations en route to Las Cruces.
- 7:00 p.m. Working dinner/roundtable presentations. Please see attendees list for roundtable presentation topics.

Tuesday, March 5

- 8:00 a.m. Working Breakfast

Items of Business:

- NASA's Aeronautics Blueprint (presented by Brent Bowen on behalf of Bruce Holmes)

- Future Symposia/Sponsorships:

1. Aviation World's Fair, April 2003 (tentative co-sponsor with LaRC). Fred Striz (OK) volunteered to help with this.
2. Langley Research Center, December 15-16, 2003 to precede Centennial of Flight Celebration at Kitty Hawk

- Journal of Air Transportation Update

- Working Group Considerations:

1. Elections for Chair will be held at the DC Space Grant Directors Meeting (March 20-24).
2. Unanimous endorsement of the *Crawl, Walk, Run, Fly!* Workshop to be held in Boulder, CO (June 20-22)
3. Ongoing collaboration/opportunities with ASA, SATS, and the Spaceport initiative.
4. A NASA EPSCoR Caucus will be held at the DC Space Grant Directors Meeting in March.

Aerospace Technology (AERONAUTICS) Enterprise Working Group

Dr. Brent Bowen, Chair • nasa@unomaha.edu

Minutes from past meetings are posted at: <http://www.unomaha.edu/~nasa/aeronautics/meetings.htm>

Geo-Referenced Altitude Hold for Latex Balloons

A Paper for

Aerospace Technology Symposium 2002

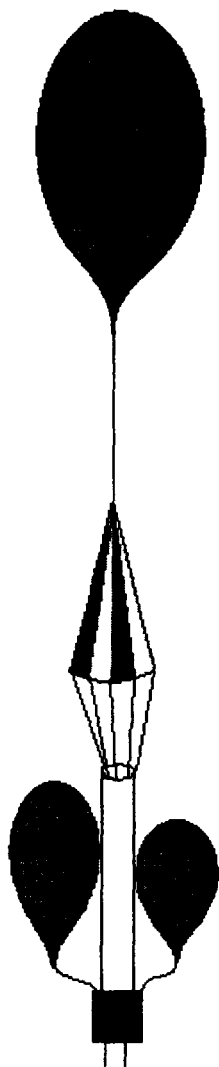
By

William J. Byrd, Michael J. Cook

7 November 2001

ABSTRACT

The capability to fly a balloon payload at a constant pressure altitude using a fixed-volume envelope has existed for decades. (NASA Scientific Balloon Facility Mission, History, and Accomplishments, <http://master.nsbf.nasa.gov/mission1.html>). However, the fixed-volume envelopes are expensive relative to latex balloons for small payloads (≤ 100 lbs). A capability to fly small packages at a constant GPS-referenced altitude using latex balloons has been developed at Iowa State University. The concept uses multiple balloons of differing sizes, GPS position data, and a ballast system. The hold altitude does not need to be determined pre-launch, allowing for holding at an altitude based upon in-situ sensor data in real time. The system has been flight tested and used for a research mission by the NASA Jet Propulsion Laboratory through a contract with the University of Iowa. Although not an automated system, it has the potential to be automated at a future date.



CONCEPT

The payload is attached to a main lift balloon with a parachute (See Figure 1). The main lift balloon is filled to provide lift equal to the weight of the total system, less 3 lbs. Two other control balloons are attached to the payload to control ascent and descent. The ascent balloon is filled to provide 3 to 5 lbs of lift, depending upon the desired ascent rate. The descent balloon is filled to 2 lbs. In addition, a food-grade antifreeze solution (propylene glycol) provides 2 lbs of ballast, which can be dumped, on command, in approximately 2 ounce increments.

At the time of launch of the system, total balloon lift is:

$$L = B_1 + B_2 + B_3$$

Where B_1 = weight of the total stack (includes payload, lines, parachute, etc.) – 3 lbs

B_2 = 2 lbs

B_3 = 3 to 5 lbs

Figure 1. Payload Configuration.

Therefore $L >$ stack weight by 2 to 4 lbs and positive lift is provided to the entire system.

Once the desired hold altitude is known, the system is allowed to ascend above that altitude approximately 1000 meters. At that point a command is sent to release B_3 , resulting in $L <$ stack weight by 1 lb and the system begins to descend. Commands are immediately sent to begin dumping ballast. The GPS system sends a telemetry string back to the ground every 4 seconds. Dump commands are sent until the system descent rate levels off to zero. Care must be

exercised to not dump too quickly. Once the system begins ascending again, there is no way to descend except to terminate the flight by cutting the second control balloon (or the main lift balloon) free. If the second control balloon is released then $L = B_1$ and the system begins to descend. A release for the main lift balloon is also provided for backup purposes, should the other release mechanisms fail.

This concept was tested and perfected over eight HABET missions from March to November, 2000. The final mission was HABET H43 – the NASA JPL test flight. The altitude plot for H43 is shown in Figure 2. After launch, the payload ascends linearly at approximately 2.4 m/s until the Ascent Balloon (B_3) is released. Once the lift of B_3 is gone, the payload immediately stops and begins to descend – this is clear from the sharp peak at the top of the plot. The payload descends at approximately 2.6 m/s, until ballast is released. This begins to happen approximately 1 minute after B_3 is released. Ballast dumps are continued every 30 seconds until the payload descent slows to less than 0.3 m/s. At this point the operator must determine if the intended flight profile can be met. The operator can continue to dump ballast with longer intervals between dumps to try to stop the descent and also prevent further ascent of the payload, if required. The altitude profile for H43 shows an essentially flat trajectory with a slight ascent rate of 0.06 m/s. A total of 11 ballast dump commands were sent to accomplish this trajectory. Once the experiment onboard the payload was completed, the Descent Balloon (B_2) was released and the payload began a descent trajectory of approximately 1.9 m/s until landing.

Further analysis of the altitude data shows several important points. The maximum error relative to the target altitude (a perfectly flat trajectory) is approximately 1.6%. It is estimated that the actual position of the balloon could be within a 60 meter range, due to GPS variations. The

flight parameters from JPL were to fly a level trajectory anywhere within a minimum altitude of 3658 meters to a maximum altitude of 4572 meters. The Altitude plot shows that this was clearly met. Further extrapolation of the trajectory shows that the altitude hold could have lasted as long as 193 minutes without exceeding the maximum altitude specified by JPL.

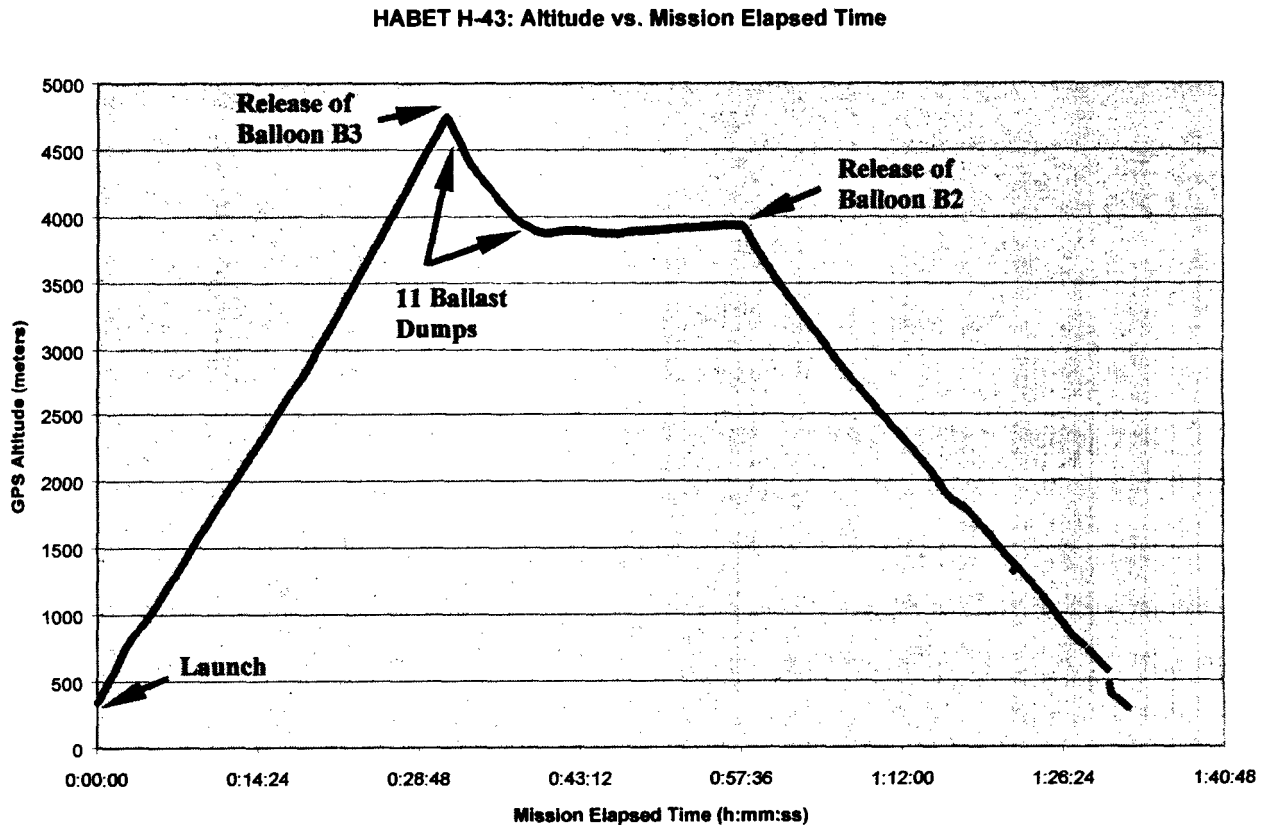


Figure 2. HABET Mission H43 GPS Altitude Plot.

SYSTEM OVERVIEW

The command and control electronics used for the altitude hold system includes standard commercial-off-the-shelf (COTS) components and several custom-designed circuit boards. The heart of the electronics is the LSB-1, shown in Figure 3. The LSB-1 is the main electronics package that currently flies on all balloon flights at Iowa State University. The LSB-1 consists of a commercial GPS unit and antenna (Motorola Oncore GT+), a MIM Module to packetize

GPS and data into the AX.25 protocol and then transmit this telemetry into a 1200 baud AFSK signal that gets fed into an FM transmitter operating in the 70cm Amateur Radio Band. The LSB-1 also contains an emergency radio beacon running on a separate power supply in the event of the failure of the main transmitter. The Radio Beacon consists of a 70cm transmitter that is modulated by a pinhole camera. This enables the payload to have a live video feed during flight, although the range of the video transmission is limited.

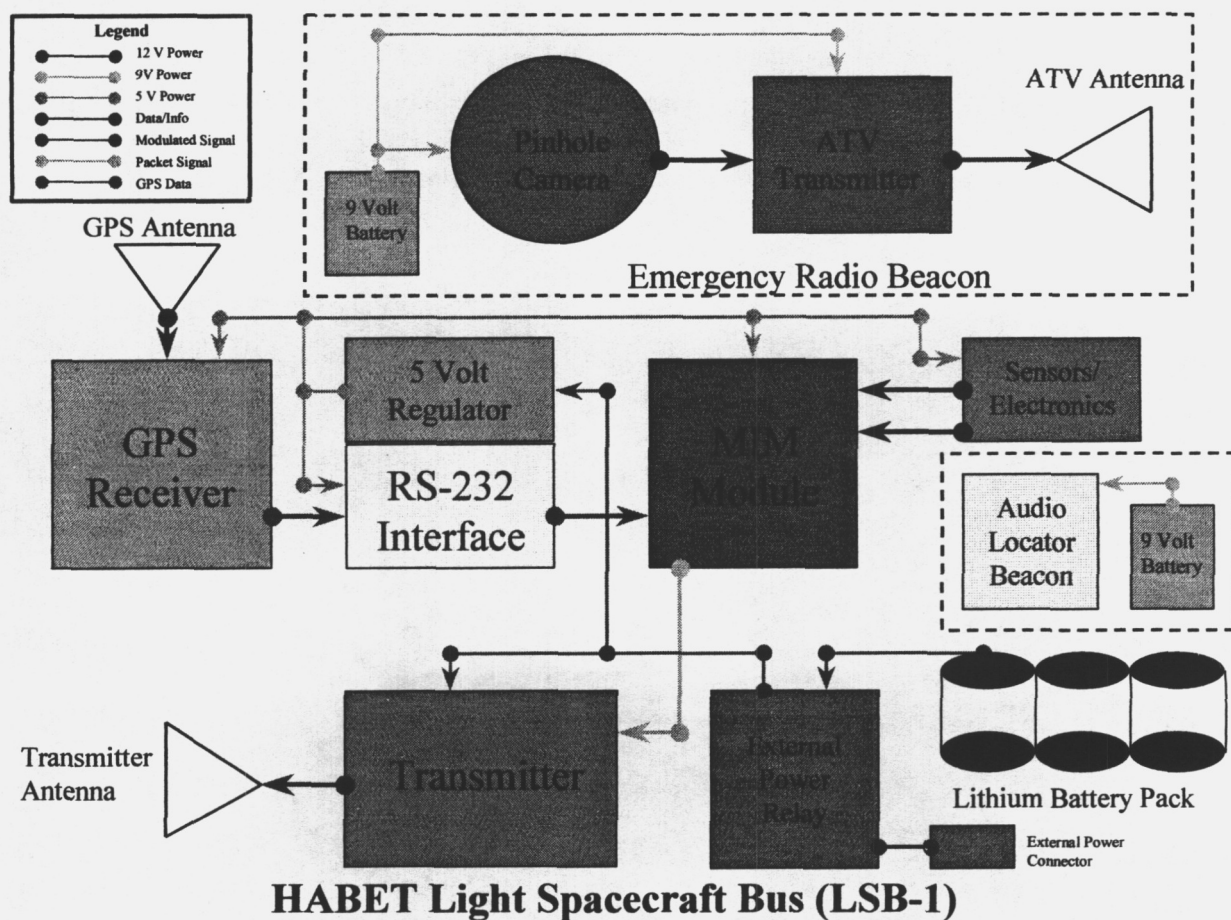


Figure 3. HABET LSB-1 Block Diagram.

With the LSB-1 as the core, several other components were added to the system to accomplish the altitude hold capability. These custom-designed components include two Altitude Switch Boards and the DTMF Relay Board. The DTMF Relay Board is designed to take a series of

standard DTMF or touch-tone tones as inputs. Once the appropriate code has been received, the board will activate a series of relays that allow the payload to release balloons or dump ballast. The Altitude Switch is designed to take a standard NMEA 0183 GPS data string as input and to output a series of TTL-level digital outputs.

SYSTEM OPERATION

After the payload has been launched and has reached the specified altitude (plus approx. 1000 feet to allow for drop), a DTMF command sequence is transmitted from the base station radio. This radio signal is received on a 2m Amateur radio receiver (Figure 4). After signal demodulation, the audio tone is fed into the DTMF Relay Board (Figure 5).

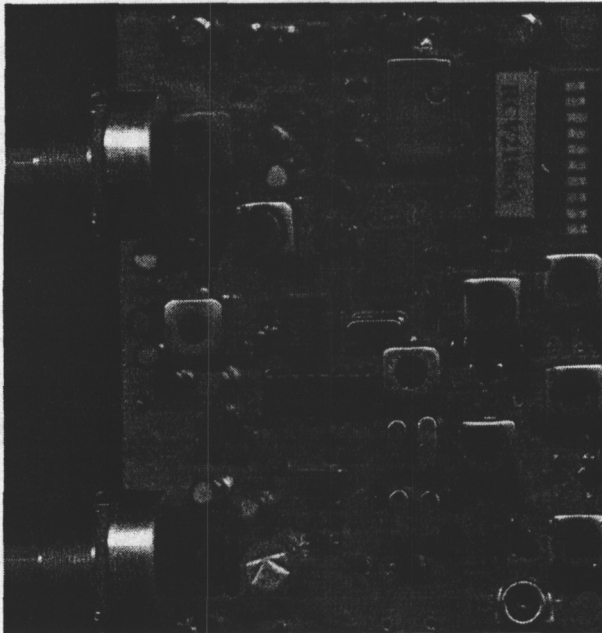


Figure 4. 2 Meter FM Receiver.

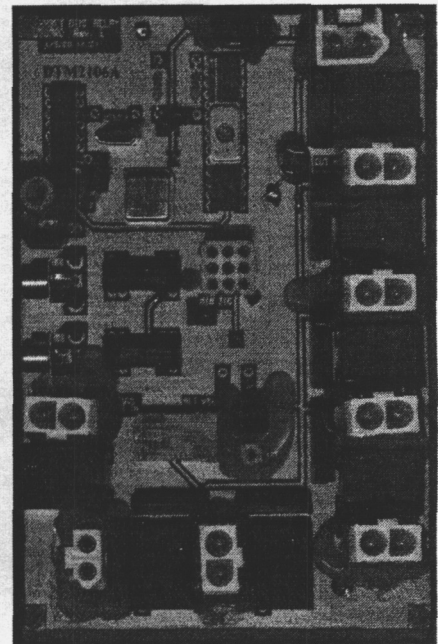
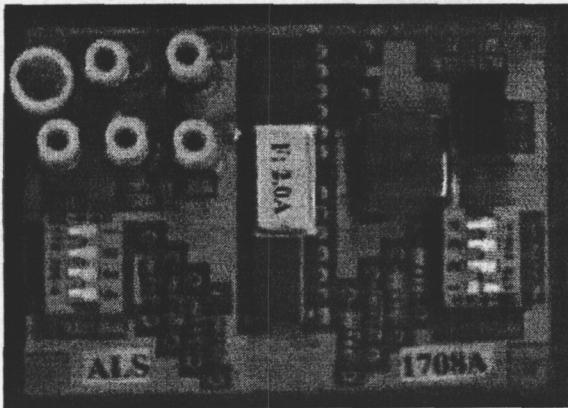


Figure 5. DTMF Relay Board.

A DTMF decoder IC (Harris CD22204) then interprets the DTMF tones and outputs 4 bit data at TTL logic levels. These 4 bits are then fed into a Microchip PIC16C73 microcontroller for further decoding. Once an appropriate code sequence has been received, the PIC will set output

ports to a logic value that can trigger the different relays on the DTMF Relay Board. The relays are used for releasing balloons and performing the ballast dump. To perform a balloon release the contacts of a specified relay close, thus energizing a NiChrome wire element that burns the kite string that anchors the balloon to the payload. The ballast dump is performed in a similar fashion, except that the relay energizes a solenoid valve that opens for 8 seconds. This will allow approximately 2 ounces of fluid to be released. Successive commands are used to dump more ballast.



The Altitude Switch Boards (Figure 6) are used for back-up in case of loss of radio contact with the payload. These boards input a standard serial NMEA 0183 GPS signal into a Microchip PIC16C73. Each Altitude Switch can be preprogrammed for TTL outputs at various altitudes

Figure 6. Altitude Switch.

based on DIP switch settings that are set prior to flight. The PIC reads in the GPS signal and strips away all data except for the GPS altitude. This is then mathematically manipulated to determine which TTL outputs are to be triggered. These outputs include an output for a specific altitude on ascent, an output for a specific altitude on descent, payload ascending, payload descending, and an incremental output that triggers at specific height intervals (i.e., every 1000 feet).

The first Altitude Switch is connected in parallel with the relay that operates the first balloon release. It acts as the first backup system. If the radio communications are inoperative, the Altitude Switch will trigger the relay at some point slightly above the optimum altitude for release. This ensures that the balloon will be released, allowing the payload to start on a descent trajectory.

The second backup is a timer that is activated as soon as the first balloon is released. It is a simple programmable timer that will cut the second balloon (to start descent from hold position). The time length is determined prior to launch.

The second Altitude Switch acts as the third and final back-up system. It operates a relay that will release the main lift balloon if a preset altitude is exceeded. This can only happen if all communication with the payload has failed and the other back-ups have not worked correctly. This ensures that the mission does not fly too high or become totally unrecoverable because of flight time and distance traveled.

The completed Command and Control Bus is shown in Figure 7. The LSB-1 is in the center, with two ballast tanks situated on either side of it. Each tank can hold approximately 16 ounces of food-grade propylene glycol.

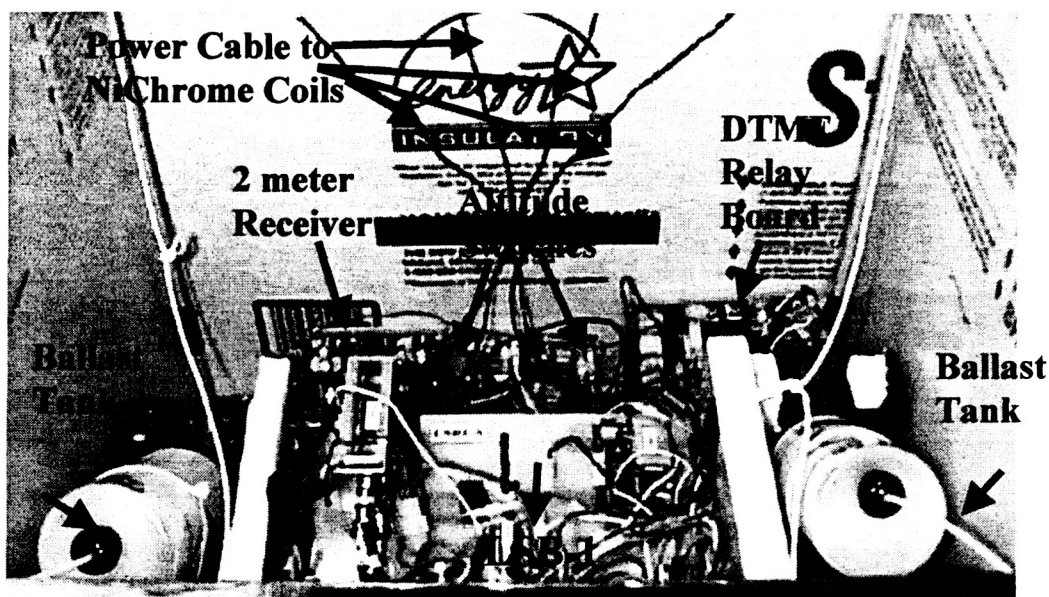


Figure 7. Complete Bus Arrangement.

CONCLUSION

This technique of holding a geo-referenced altitude is a promising and affordable alternative to other systems when the sensor packages are small (~ 100lbs) or when the hold altitude is not known in advance of launch. This system could easily be modified to provide an automated hold capability. This would mean that an intended altitude would be entered in prior to launch, and then the spacecraft would automatically determine the balloon release sequence and the number of ballast dumps to achieve a level trajectory. This would be advantageous, since radio command to the balloon cannot always be easily achieved. Another improvement would be to add several more balloons. This would allow the possibility of having several altitude hold levels that could be achieved during one flight. Though the altitude in this case was low in comparison to many balloon flights, the process could also be adapted for most other altitudes

where scientific ballooning is common. Finally, though the payload weight in the JPL flight was small (28 lbs.), it is believed that this payload weight could easily be increased to the 100 lb. range with little difficulty.

**NASA Spaceport Research:
Opportunities for Space Grant and EPSCoR Involvement**

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for

The National Space Grant Aerospace Technology Working Group

Aerospace Technology Symposium 2002

Las Cruces/NASA White Sands Test Facility, New Mexico

March 3-5, 2002

An Overview of Capabilities

Rationale

Over the last decade, the high cost of space programs has led to a significant decrease in space exploration and supporting programs. Current launch and recovery systems are too expensive to operate and maintain. In 1994, Congress passed the National Space Transportation Policy, which called on the National Aeronautics and Space Administration (NASA) to pursue “technology development and demonstration efforts to support future government and private sector decisions on the development” of operational second- and third-generation reusable launch vehicles.

In response to the congressional mandate, NASA has undertaken a strategic initiative to expand future space exploration by encouraging commercialization and privatization of spaceport and launch functions (Goldin, 2001). This initiative’s success depends on a two-fold plan. The first part involves the development of new and advanced enabling technologies, which will produce cost-effective and commercially viable recoverable launch vehicles (RLVs). The second portion of the plan creates a national space transportation architecture that appears to parallel the commercial airline industry (ASTWG, 2002).

To support the development of revolutionary new technologies, NASA initiated the Integrated Space Transportation Plan (ISTP) managed by a partnership consisting of NASA, industry, the Department of Defense and academia (Vannieri, 2001). In the near term, this partnership will determine an appropriate course of action and provide funding for America’s space shuttle program. In the long term, the ISTP will use funding under

the Space Launch Initiative (SLI) to produce the technology that will yield second-generation and follow-on RLVs (Goldin, 2001).

To build a new national space transportation system, NASA is pursuing commercialization and privatization of spaceport functions. In support of this new strategy, NASA Kennedy Space Center formed the Advanced Spaceport Technology Working Group (ASTWG) in 2001 (ASTWG, 2002). ASTWG is a partnership comprising NASA, industry, the Department of Defense, academia, and state and federal agencies. ASTWG's mission is to provide a forum in which interested parties work together in the development of space technologies, governmental regulatory policies, and business enterprise models that will promote successful commercial spaceport growth within the United States.

ASTWG is currently finalizing charter and vision statements as well as establishing functional working relationships between NASA, state and federal agencies, private aerospace industry, and academia. The nation and aerospace industry currently lack a defining vision and business enterprise model that would ensure the continued exploration and development of space. Without a defining vision and the accompanying financial incentive, American space exploration will likely make little progress. Substantial program development is needed not only in technical areas, but also in policy, business enterprise models, information collection and sharing, and organizational strategic planning. The focus of the University of Nebraska at Omaha is to explore the needs of NASA and its partners, then provide research supporting the goal of scientific exploration and commercialization of space.

The Economics of Spaceports

American space exploration efforts have spawned countless revolutionary technological innovations that have helped propel the American technological revolution into the 21st century. The nation's space exploration initiative has significant economic impact on national productivity and welfare. The economic impact of space exploration, while national in scope, is most readily apparent in states and communities that currently maintain and operate spaceports.

Money spent on space exploration has substantial impact far beyond the operation and support of the spaceport facility itself. Dr. D. Lenze's (2001) study of the economic impact of NASA and supporting industries on central Florida revealed that in 2000, NASA's operations generated \$940 million of revenue. This expenditure further produced \$1.72 billion in regional private firm output of goods, supporting over 19,000 jobs encompassing private and public sectors. Total employee compensation from these jobs was approximately \$705 million. The addition of each \$1 million of revenue from the Kennedy Space Center is estimated to increase output of the central Florida region by \$1.64 million, producing a final-demand multiplier of 1.64. An additional 25 jobs would be required to support a \$1 million increase in KSC revenue, producing an estimated additional \$830,000 in salaries (Lenze, 2001). The potential growth and expansion of spaceport facilities throughout the United States, *paralleling* the current commercial airline industry, would create substantial economic benefit for participating states and regions.

The economic and military benefits of space exploration and development have motivated many nations to join a new *space race*, a race in which the United States is

falling behind. Worldwide commercial launch activity for 2001 was one of the worst in history, with U.S. commercial launches at the lowest level since the Challenger disaster of 1986. In 2002, the U.S. is projecting to launch eight satellites, matching the number projected to be launched by Europe alone (Futron, 2001). The American commercial launch industry is suffering from the competition of highly reliable and cost-effective Russian and French launch vehicles. Unfortunately, the most serious problem with American space competitiveness is its own unresponsiveness to changes in the market (Futron, 2001). The International Reference Guide to Space Launch Systems lists 28 international spaceport facilities, of which 5 (Kodiak is now active though listed by the authors as not yet operational in 1999) are under active U.S. control (Isakowitz, Hopkins & Hopkins, 1999). The other launch facilities are controlled and operated by Russia, France, India, Italy, Spain, Israel, China, Japan, Brazil, Britain, and Australia. International access to space is growing rapidly. If the United States does not pursue new space launch programs, it will lose billions of dollars in revenue to emerging overseas competitors and forfeit its role as the world's technology leader.

The AWTG Concept

NASA Kennedy's sponsorship of AWTG is an initial step in the development of commercially viable, privately operated space transportation systems. NASA, industry, and states—along with federal and academic partners—are currently forming the organizational relationships that will sponsor and produce new spaceport enabling technologies and transportation structures.

Specific interests of the group not only involve the development of new launch systems, but new facility and infrastructure support systems including facility design,

logistical lines, and supporting transportation systems. Funding for spaceport development is critical. Future sources of funding—whether private, local, state or federal—are of critical importance. State and federal policies concerning spaceport regulation, operation, environmental impact, and international negotiation of over-flight and alternate/emergency landing agreements are additional areas of concern.

In preparation for addressing issues of cross-sectoral partnerships, ASTWG is forming its own organizational identity and goals. At the present, the group is working towards the completion of vision and mission statements and clarifying the legal status of a federal agency project involving people from outside the government. NASA, itself, is at a historically significant transitional stage. It is shifting from its role as the chief developer and operator of space vehicles to that of the “facilitator” and “coordinator” of private enterprise and government. NASA has taken substantial steps in organizing interested parties, but there is still much organizational work to be completed for the ASTWG partnership to become an organization capable of promoting and advising in commercial spaceport enterprises.

University of Nebraska’s Research Capabilities

The University of Nebraska possesses an experienced research faculty with a broad range of experience in both transportation systems and critically interrelated components. The university has developed a set of interrelated research tools, including (a) systems engineering and the development and testing of mathematical/computer models; (b) economic modeling; (c) organizational development and team building assistance; and (d) the assessment of the potential to develop additional network-based organizations to support broad-based research efforts.

Research assessment of the spaceport commercialization and privatization initiative will require funding and support from multiple sources. University of Nebraska research will be designed to support ASWTG in this effort. Research components in this activity would include (a) University of Nebraska faculty from multiple campuses and disciplines; (b) participating Space Grant/EPSCoR members; (c) NASA research center personnel, (d) federal, state, and local government participants; and (e) industry representatives. Supporting ASTWG's goals and needs, the University of Nebraska could (a) engage additional faculty and student resources from participating institutions to meet specialized needs, (b) coordinate research activities and priorities in response to the recommendations of the ASTWG advisory board at NASA Kennedy as well as other ASTWG partners, and (c) aid in the development of outreach mechanisms designed to educate and engage the public in support of the spaceport commercialization and privatization concept.

The University of Nebraska is ready to design a research program that will support ASTWG in the formulation of spaceport initiative policies and systems. The Nebraska research group is highly qualified to assist NASA in development of a spaceport commercialization and privatization strategy that ensures America's prominence as the world's leader in space exploration and development.

Conclusion

The commercialization and privatization of space launch systems could lead to a new era in space exploration and development in the United States. This is a historic undertaking that requires extensive research, innovation, and determination if it is to succeed. The economic and social gain to be realized from successful commercial

venture into space is not limited to America. It is not a question of whether space will be developed, it is a question of when—and this is an opportunity for the United States to reassume its leadership role in space exploration and development.

Further Information

If you would like further information regarding the Spaceport Commercialization and Privatization Plan or would like to collaborate with the Nebraska CRT, please contact:

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This overview was prepared by Mr. Patrick O'Neil, Dr. Richard Box and Dr. Brent Bowen.

**NUMERICAL SIMULATION OF THE COMBUSTION OF FUEL DROPLETS:
AN AEROSPACE TECHNOLOGY OVERVIEW**

Presented by:

Mary Fink

Authors of attached paper,

*Numerical Simulation of the Combustion of Fuel Droplets; Finite Rate Kinetics and
Flame Zone Grid Adaptation (CEFD)*

A NASA Nebraska Space Grant and EPSCoR Sponsored Research Endeavor

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for

The National Space Grant Aerospace Technology Working Group

Aerospace Technology Symposium 2002

Las Cruces/NASA White Sands Test Facility, New Mexico

March 3-5, 2002

Running head: Combustion of Fuel Droplets

**Numerical Simulation of the Combustion of Fuel Droplets;
Finite Rate Kinetics and Flame Zone Grid Adaptation (CEFD)
A NASA Nebraska Space Grant and EPSCoR Sponsored Research Endeavor**

George Gogos, Ph.D. – Principal Investigator

University of Nebraska – Lincoln

Brent D. Bowen, Ph.D. and Jocelyn S. Nickerson, MPA

University of Nebraska at Omaha

Draft Date: June 4, 2002

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Abstract

The NASA Nebraska Space Grant (NSGC) & EPSCoR programs have continued their effort to support outstanding research endeavors by funding the Numerical Simulation of the Combustion of Fuel Droplets study at the University of Nebraska at Lincoln (UNL). This team of researchers has developed a transient numerical model to study the combustion of suspended and moving droplets. The engines that propel missiles, jets, and many other devices are dependent upon combustion. Therefore, data concerning the combustion of fuel droplets is of immediate relevance to aviation and aeronautical personnel, especially those involved in flight operations. The experiments being conducted by Dr. Gogos' and Dr. Nayagam's research teams, allow investigators to gather data for comparison with theoretical predictions of burning rates, flame structures, and extinction conditions. "The consequent improved fundamental understanding of droplet combustion may contribute to the clean and safe utilization of fossil fuels" (Williams, Dryer, Haggard & Nayagam, 1997, ¶ 2). The present state of knowledge on convective extinction of fuel droplets derives from experiments conducted under normal gravity conditions. However, any data obtained with suspended droplets under normal gravity are grossly affected by gravity. The need to obtain experimental data under microgravity conditions is therefore well justified and addresses one of the goals of NASA's Human Exploration and Development of Space (HEDS) microgravity combustion experiment.

**Numerical Simulation of the Combustion of Fuel Droplets;
Finite Rate Kinetics and Flame Zone Grid Adaptation (CEFD)**

A NASA Nebraska Space Grant and EPSCoR Sponsored Research Endeavor

Rationale

“The engines that propel missiles, jets, and many other devices are dependent upon combustion. Liquid fuel is sprayed into an engine chamber where it evaporates and burns, generating the thrust that propels the object forward” (Mashavek, 2001, ¶ 1). The amount of thrust created depends on many factors, including pressure, temperature, the fuel droplet evaporation rate, and turbulence. Therefore, data concerning the combustion of fuel droplets is of immediate relevance to aviation and aeronautical personnel, especially those involved in flight operations.

“The combustion of fuel droplets is an important part of many operations, such as the heating of furnaces for materials processing or home heating, power production by gas turbines, and combustion of gasoline in a car's engine” (Williams, Dryer, Haggard & Nayagam, 1997, ¶ 2). The Earth's gravity prevents many theoretical predictions involving fuel droplet combustion. Additionally, drop towers and aircraft are unsuitable for this type of experimentation due to time constraints and unacceptable levels of microgravity. The experiments being conducted by Dr. Gogos' and Dr. Nayagam's research teams, allow investigators to gather data for comparison with theoretical predictions of burning rates, flame structures, and extinction conditions. “The consequent improved fundamental understanding of droplet combustion may contribute to the clean and safe utilization of fossil fuels” (Williams, Dryer, Haggard & Nayagam, 1997, ¶ 2).

The present state of knowledge on convective extinction of fuel droplets derives from experiments conducted under normal gravity conditions. “Due to the increase in the extinction

velocity with droplet diameter, under extinction conditions natural convection becomes negligible at large 'droplet' (porous sphere) diameters and important at smaller droplet diameters" (Bowen, Woods, Narayanan, Smith, & Gogos, 2000, 4.3.3 p. 1). As a result, any data obtained with suspended droplets under normal gravity are grossly affected by gravity. The need to obtain experimental data under microgravity conditions is therefore well justified and addresses one of the goals of NASA's Human Exploration and Development of Space (HEDS) microgravity combustion experiment.

NSGC & EPSCoR Background and Research Involvement

The Nebraska Space Grant Consortium at the University of Nebraska at Omaha develops research infrastructure and enhances the quality of aerospace research and education throughout the state. This grant provides national leadership in applied aspects of aeronautics and allows Nebraska colleges and universities to implement a balanced program of research, education, and public service programs related to aeronautics, space science, and technology. The grant administers funds to recruit and train professionals for careers in the aerospace industry.

EPSCoR (Experimental Program to Stimulate Competitive Research) assists states with low levels of federal research and development support, thus responding to a Congressional concern about increasing the geographic base of federal research support. Nebraska EPSCoR is a statewide effort, which provides leadership for development of research and development in science and engineering throughout the state. Specific to the University of Nebraska at Omaha is the Aeronautics Education, Research, and Industry Alliance (AERIAL), a comprehensive, multi-faceted, 5 year NASA EPSCoR 2000 initiative. This contributes substantially to the strategic research and technology priorities of NASA while intensifying Nebraska's rapidly growing aeronautics research and development endeavors.

The partnership between the NASA Nebraska Space Grant (NSGC) & EPSCoR programs allows for the selection of outstanding research projects that positively impact aeronautical technology advancement. These programs have continued their effort to support such research endeavors by funding the Numerical Simulation of the Combustion of Fuel Droplets study at the University of Nebraska at Lincoln (UNL).

The CEFD Concept

Dr. Vehda Nayagam guides the Microgravity Combustion Science Program in San Diego, CA. This program is conducting a project flight definition experiment to obtain data under microgravity conditions. The UNO CEFD collaborative research team (CRT) is developing a new comprehensive numerical model for the convective extinction of fuel droplets to validate this model. The data collected from each institution contributes to one of the long-term goals of the HEDS microgravity combustion program. Specifically, that which promotes “understanding that will permit lessons learned in microgravity combustion experiments and modeling to be used in optimizing combustion devices here on Earth.”

A team of researchers from the University of Nebraska – Lincoln, led by Dr. George Gogos, is conducting a comprehensive computational study of fuel droplet combustion at atmospheric pressure and zero-gravity ambient conditions under forced convection. Through a collaborative effort with NASA Glenn Research Center, Dr. Gogos and his colleagues are developing a science education component that demonstrates how the combustion process changes due to microgravity.

Simplified as well as detailed chemical kinetics are employed in the research. The studies provide insights that can be applied to improve liquid fuel combustion with greater efficiency and safety, and reduce environmentally-adverse effects. In view of the detailed

chemical kinetics, substantial complexities and uncertainties are involved in modeling combustion of a moving droplet through the currently finding experimental research on combustion of a moving droplet through the Microgravity Combustion Science Program.

The research focuses on the validated modeling of two key topics: a) Transient combustion of a moving droplet with simplified chemical kinetics; and b) Transient combustion of a moving droplet with detailed chemical kinetics. The first topic is currently being addressed, whereas the second one is a longer-term research project. This work is a direct extension of research funded by the NASA Nebraska Space Grant and EPSCoR Programs. “Dr. Gogos’ studies on droplet combustion at atmospheric pressure include combustion of moving droplets with infinitely fast kinetics as well as with one-step global kinetics” (Bowen, Holmes, et al. 1999, p. 19).

Research success depends on the team’s considerable experience combined with recently published studies on comprehensive modeling of hydrocarbon oxidation, which employ detailed chemical kinetics. Dr. Gogos’ doctoral student, Daniel Pope, is supported under the NASA Nebraska Space Grant and EPSCoR Programs. He has been working for over two years simulating combustion of a moving droplet with one-step kinetics and contributes immensely to the timely completion of the proposed work.

Additionally, data obtained from NASA sponsored studies are available in current literature and additional data will soon become available. This model will be compared and validated against these experimental data. The UNO CEFD team “expects to capture the nonlinear interaction between hydrodynamics and detailed chemical kinetics, which will lead to an extremely valuable appropriately-validated model for combustion of a moving fuel droplet” (Bowen, Holmes, et al., 1999, p. 19).

Research Progress

The current CEFD CRT research has focused on the development of a validated numerical model for droplet combustion in a forced convection environment. Funded by the previous five-year NASA EPSCoR grant, a quasi-steady numerical model, which utilized one-step overall chemical kinetics and a single diffusion coefficient to describe the mass diffusion, was developed to study the convective extinction of fuel droplets under zero-gravity conditions (Gogos, Pope, & Lu, 2001, p. 2). As a result of suggestions made in the review of the 2001 Pope and Gogos article and as a prelude to incorporating multi-step chemical kinetics schemes, the quasi-steady code is currently being modified to allow for the different mass diffusion coefficients associated with each pair of chemical species. This modification to the quasi-steady code is part of the systematic addition of modeling complexities that was presented in the original research proposal. The end goal of the research is to develop an experimentally validated droplet combustion model that can be used for accurate predictions of single droplet behavior in practical combustion systems.

The conditions present in convective droplet combustion experiments are different from those present in practical combustion systems. Droplet combustion experiments under forced convection are conducted by suspending the fuel droplet from a silica fiber in an ambient oxidizer at a fixed temperature (T_∞) and pressure (p_∞), as shown in Figure 1. The oxidizer is "blown" over the droplet at some fixed velocity (U_∞). If the ambient temperature is high enough, or if an external ignition source is present, the droplet will ignite. The initial flame configuration (wake, transition, or envelope) depends on the "blowing" velocity. In practical combustion systems, droplets are injected into a combustion chamber. This situation is shown in Figure 2, where the droplet is injected, at some initial velocity, into a stagnant environment at a

specified temperature and pressure. The moving droplet experiences a drag force that opposes its motion and the droplet velocity decreases. The initial velocity determines the initial flame configuration. If the initial flame configuration is a wake flame, the decrease in droplet velocity can result in a change from a wake to a transition flame, and finally to an envelope flame. The numerical model must be able to deal with both the suspended droplet case (for model validation) and the moving droplet case (for practical predictions). A transient code is required to model the change in droplet diameter caused by evaporation at the droplet surface, the change in flame position and configuration, the internal heating of the droplet, and the decrease in droplet velocity for the moving droplet.

A transient code has been developed to model droplet combustion in a forced convection, zero-gravity environment. One-step overall chemical kinetics and a single diffusion coefficient to describe the mass diffusion were used in the model. The model has been validated using the numerical results of the 2001 Gogos and Zhang research for the evaporation (no combustion) of n-heptane droplets in nitrogen at atmospheric pressure. Excellent quantitative agreement was observed for various ambient temperatures and initial droplet velocities.

The transient code has been used to numerically investigate the combustion of n-heptane droplets in air at atmospheric pressure. The initial droplet diameter ($D_0 = 0.5\text{mm}$), initial droplet temperature ($T_0 = 297\text{K}$), and the ambient temperature ($T_\infty = 1000\text{K}$) were fixed and the initial droplet velocity ($U_\infty(0)$) or "blowing" velocity (U_∞) was varied. Results have been obtained for moving and suspended droplets with initial Reynolds numbers of 10, 25, 50, and 100. At a given initial Reynolds number, the fixed "blowing" velocity (suspended droplet) and the initial droplet velocity (moving droplet) are equal. The numerical results indicate that the initial Reynolds number determines the flame configuration that forms during droplet ignition for both moving

and suspended droplets. An envelope flame is formed during droplet ignition for an initial Reynolds number of 10 and a wake flame is observed at the higher initial Reynolds numbers. This is in qualitative agreement with the quasi-steady code, which predicts an envelope flame for Reynolds numbers less than 12 under these same conditions. Once the initial flame configuration had formed (either envelope or wake), the suspended droplet cases exhibited the same flame configuration throughout the droplet lifetime. In the moving droplet cases, the wake flame that formed at the higher initial Reynolds numbers, gradually approached, and then eventually surrounded the droplet in an envelope flame configuration as the droplet velocity decreased. The predictions indicate a marked difference between the behavior of suspended and moving droplets.

The development of a transient droplet combustion code represents a significant step in our current research which is funded by the new five-year NASA EPSCoR grant. The modification of the quasi-steady code to include multiple diffusion coefficients is nearing completion. Once this modification is tested, it will be incorporated in the transient model. The next step will then involve the incorporation of multi-step chemical kinetics in the quasi-steady and transient models.

Research Outcomes

The CEFD CRT meets weekly to provide an opportunity for researchers to present and discuss their new results. This ensures that research objectives are being met. For additional dissemination of findings, this CRT established collaboration with both the John Glenn Research Center at Lewis Field in Ohio and the U.S. Department of Defense. Continued communication is also a priority for the CEFD team. Additionally, Principal Investigator Gogos' has maintained direct communication with Dr. Vedha Nayagam in San Diego, California. This communication

will allow the CEFD CRT's modified numerical code to be validated by Dr. Nayagam's experimental data.

A post doctorate research associate, Dr. Daniel Pope, and a research assistant professor, Dr. Hongtao Zhang, are also participants in this research project. Both researchers have set goals of becoming tenure track faculty in institutions of higher education. The weekly research meetings provide both Dr. Pope and Dr. Zhang with invaluable experience on graduate student advising. Additionally, they are strongly involved in every other aspect of the CEFD research faculty such as, writing proposals, writing papers, presenting conference papers, reviewing papers. Such mentoring opportunities are expected to continue throughout the lifetime of the research study.

Conclusion

The Numerical Simulation of the Combustion of Fuel Droplets study is one of three Collaborative Research Teams (CRT) currently supported by the NSGC & EPSCoR programs. Each CRT strives to provide the most current information to interested members of the academic world. The Numerical Simulation of the Combustion of Fuel Droplets study is an evolving project. Periodic updates are available on a quarterly basis.

Additional collaborations are sought with other organizations on a continual basis. All opportunities for collaboration are invited for consideration. Additionally, NSGC & EPSCoR welcome any input on program directions as well. The partnership between the NSGC & EPSCoR programs allows for the selection of outstanding research projects that positively impact aeronautical technology advancement. Those in the NSGC & EPSCoR program, the Collaborative Research Teams, and the industry look forward to experiencing the same high level of achievement in the future.

Further Information

If you would like further information regarding the Numerical Simulation of the Combustion of Fuel Droplets, or would like to collaborate with the Nebraska CRT, please contact:

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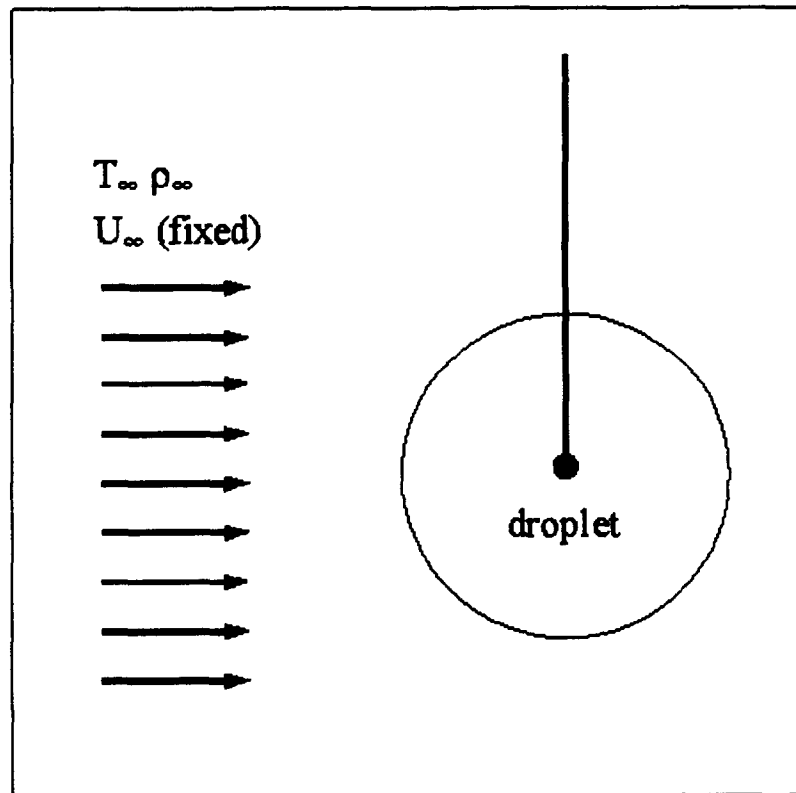
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Figure Caption

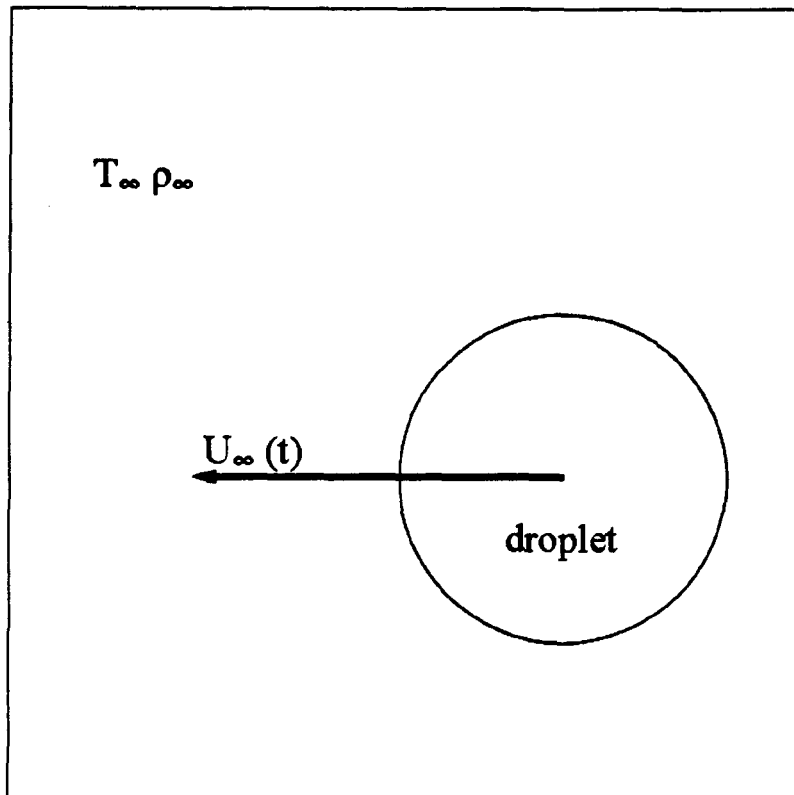
Figure 1. Orientation of single droplets for experiments

Figure 2. Orientation of single droplets within practical combustion systems.

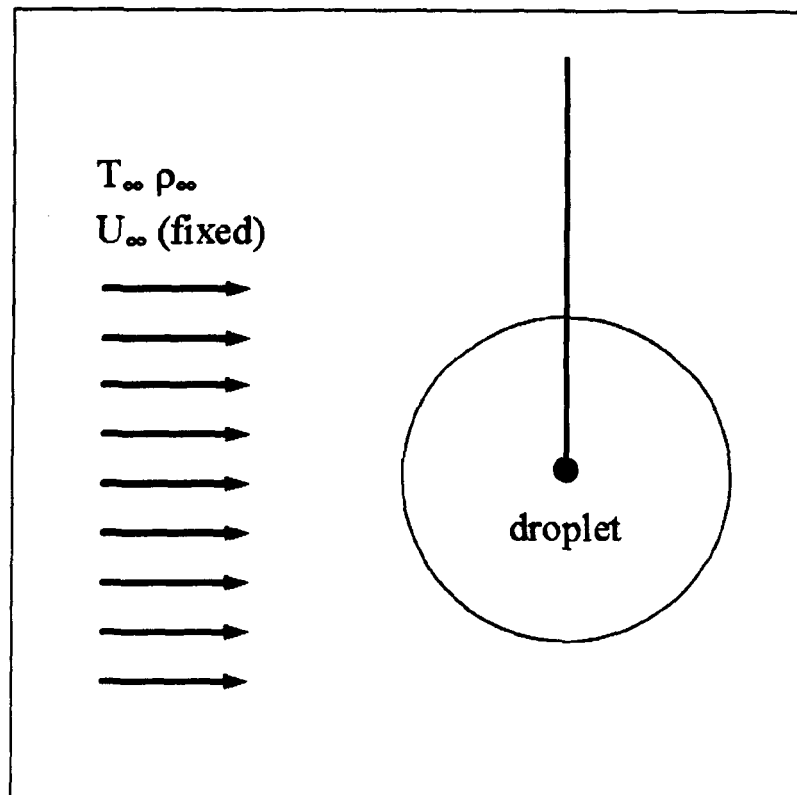
This overview was prepared by Mrs. Jocelyn Nickerson, Dr. Brent Bowen, Dr. George Gogos and various CEFD CRT members. Last update occurred on June 4, 2002 at 2:58 PM.



Suspended Droplet



Moving Droplet



Suspended Droplet

Dr. Frank R. Chavez

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Ph.D.

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M.S.

Arizona State University (Mechanical)

B.S.

Arizona State University (Aerospace)

Expertise in:

System Dynamics and Control

Control Theory and Applications

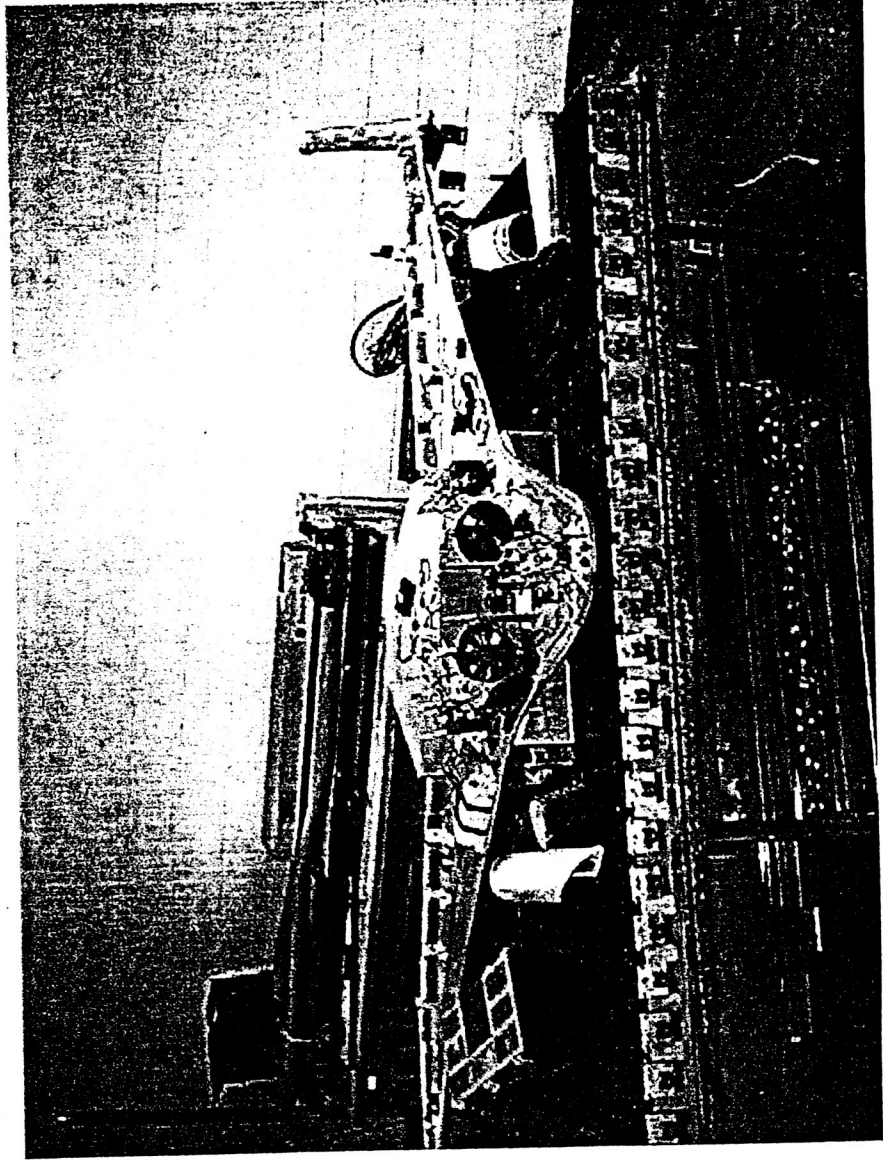
Aircraft/Spacecraft Flight Control, Guidance, Navigation

Control Systems for Autonomous Vehicle Operations

System ID \rightarrow Flight Control \rightarrow Autonomous Flight \rightarrow Autonomous Formation

graduate & undergraduate

graduate



Blended Wing Body Design

7ft Wing Span

Two (2) Internal Ducted Fans @ 12 lb Thrust (S.L.)

Initial Low-Speed Taxi Testing Mid-March (Spring Break)

Low-Level Flight and Flight Envelope Expansion (Summer)

Potential Rockwell-Collins (Cedar Rapids) Support of
Standard Flight Control System

Longitudinal/Lateral Stability Augmentation

Altitude/Heading Hold Autopilots

Seeking Funding from DARPA/NASA/Air Force/Others for...

Development and Testing of Autonomous Flight Control Systems
Single Vehicle and Group Autonomy

Design and Flight Testing of Micro-Aerial Vehicle Systems

Iowa Space Grant Consortium Funding for..

Comparison of CFD and Potential Flow Methods for
Micro-Aerial Vehicle Aeroelastic Analysis

NASA Langley has provided Wind Tunnel Data and Wing Deflection Data

Goal is develop autonomous flight control systems for this class of vehicle

Combine Blended Wing Body and Micro-Aerial Vehicle Efforts into one

Development Effort for Autonomous Flight Systems

Aeroelastic/Aeroservoelastic Efforts

Iowa Space Grant Consortium Funding for..

Robust Flutter Prediction including Structural Mode Uncertainty

NASA Dryden will provide flight test data for validation of the method
Potential funding for continuation of research (NASA GSRP Fellowship)

Above interaction has lead to involvement and potential funding for
research in NASA Dryden's Active Flexible Wing (AFW) Program

Wind Tunnel Applications

Up to 130 mph wind speed

10ft x 6ft test section

Less than 0.5% turbulence intensity

350 hp variable speed motor

1) Wing Warping Control Strategies for Optimal Performance with Aeroelastic Constraints

- Control strategies for continuous systems
- Sensor and actuator placement
- Smart materials and mechanical design

2) Micro-Aerial Vehicles

- Aerodynamics of low Reynold's number flow
- GN&C for autonomous formations

3) Wind Engineering Applications

- Tornado/High winds
- Wind energy
- Civil structures

Flight Simulation

Iowa State is home to the Virtual Reality Applications Center (VRAC)

10ft x 10ft x 10ft fully immersive synthetic environment

6 projectors 3D graphics

Mono/Stereo Graphics 3D sound

Iowa Space Grant Consortium Funding for..

Simulation of formation flying task to investigate the potential benefits
of 3D Stereo Graphics over mono graphics

Iowa National Guard has interest in developing this capability for Pilot Training

Currently working with an Iowa National Guard F-16 Pilot to simulate
F-16 Flight Dynamics and to Develop a "Flight Task" for Evaluating
3D Stereo Graphics Projection Technology

National Space Grant Student Satellite Program

William A. Hiscock

Director

Montana Space Grant Consortium

co-Chair

Space Grant Student Satellite Steering Committee

The National Space Grant Student Satellite Program

[Mission](#)[Endorsements](#)[Sponsors](#)[Members](#)[Programs](#)[Resources](#)

Across America, Space Grant students are learning from the ground up—literally—by designing, building, flying and operating a broad range of spacecraft. Students come with an interest in Space, but with different levels of skill, knowledge, and experience. Missions of growing complexity provide opportunities to acquire baseline skills and then to build on them. They range from the simple—building soda-can “satellites” or small payloads for launch from small rockets or balloons—to building sophisticated satellites. We call this strategy “crawl”, “walk”, “run” and “fly!”

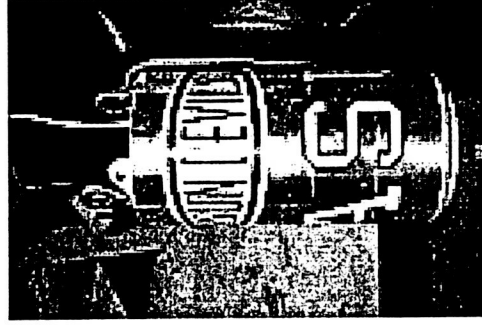
[Crawl](#)[Walk](#)[Run](#)[Fly](#)

<http://ssp.arizona.edu/sgsatellites/mission.shtml>

“CRAWL”



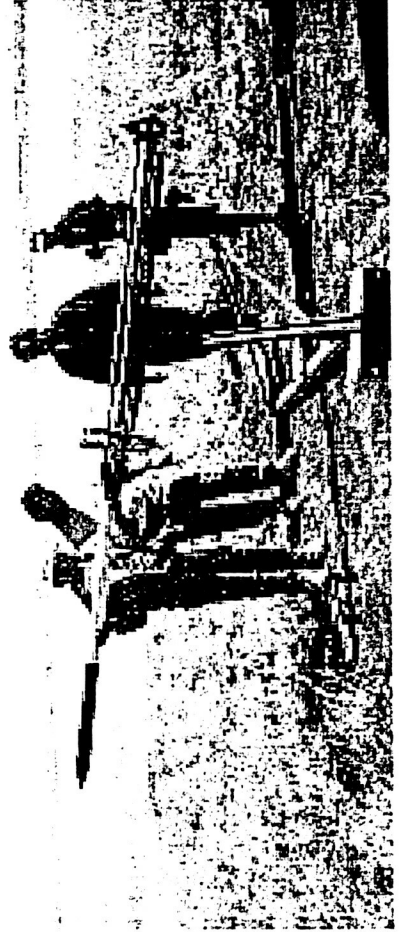
Montana BOREALIS Program



Arizona CanSats



Colorado BalloonSats



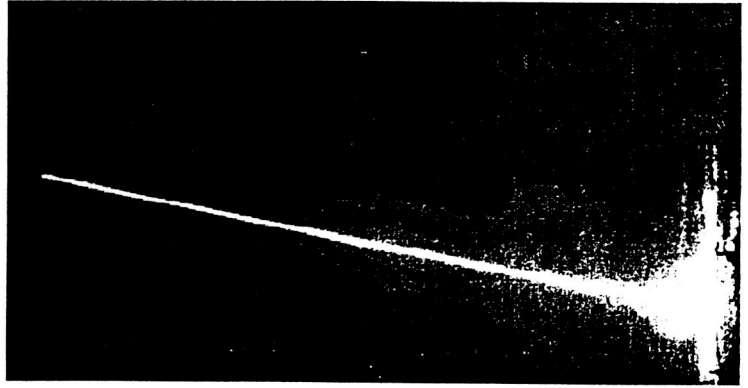


Arizona CubeSat Program

“WALK”



Montana MEROPE program



Alaska Student Sounding Rocket Program





Arizona State University
ASUSat 1

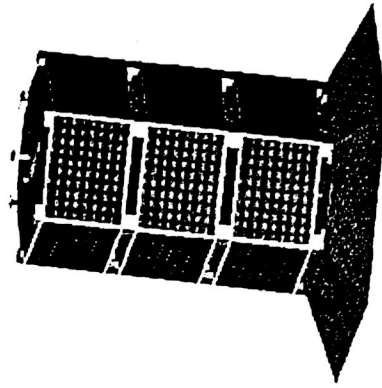


Colorado Space Grant's Citizen Explorer 1

“RUN”

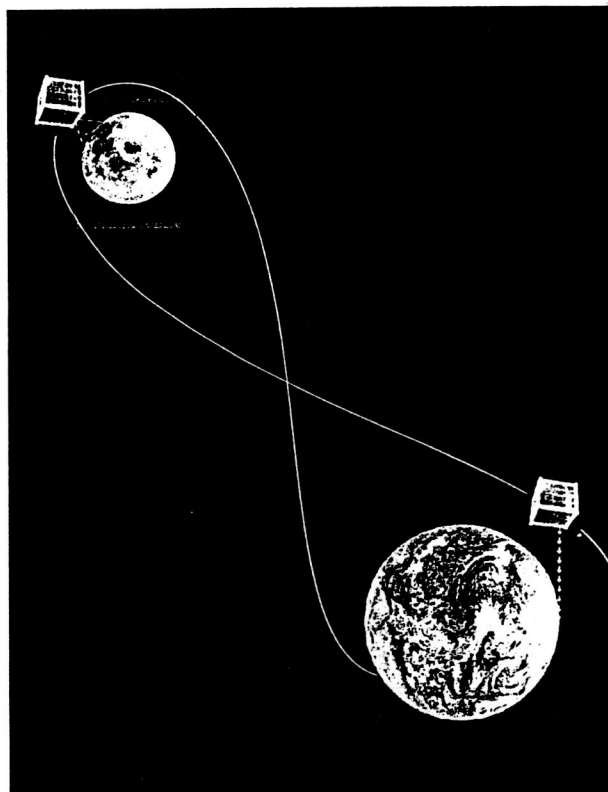


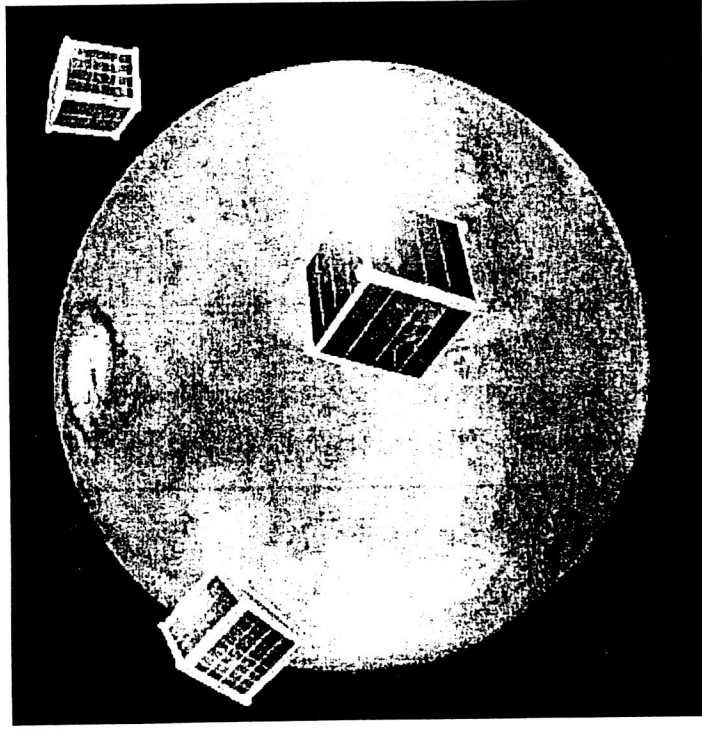
Colorado, Arizona, and New
Mexico: Three-Corner Sat



“FLY”

52 CubeSats around the Moon
in 2005-6

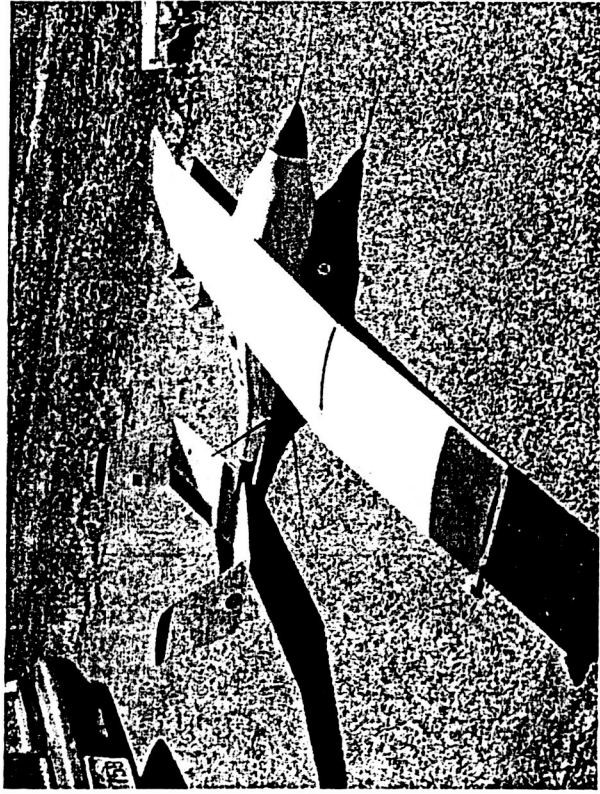




“FLY”

Ultimately we plan to send a flotilla of student satellites, representing the 52 Space Grant consortia, to Mars. This bold concept was enthusiastically endorsed by Scott Hubbard, then NASA’s Mars Program Director, (and subsequently by his successor Orlando Figueroa) in a letter of support dated January 26, 2001:

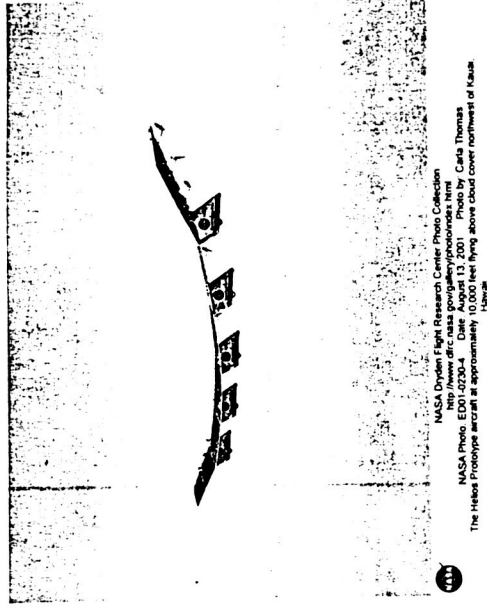
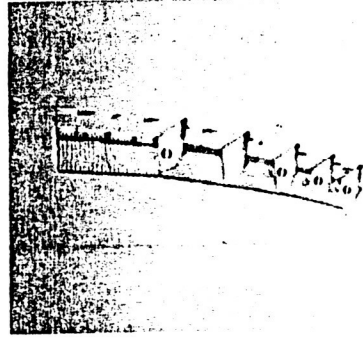
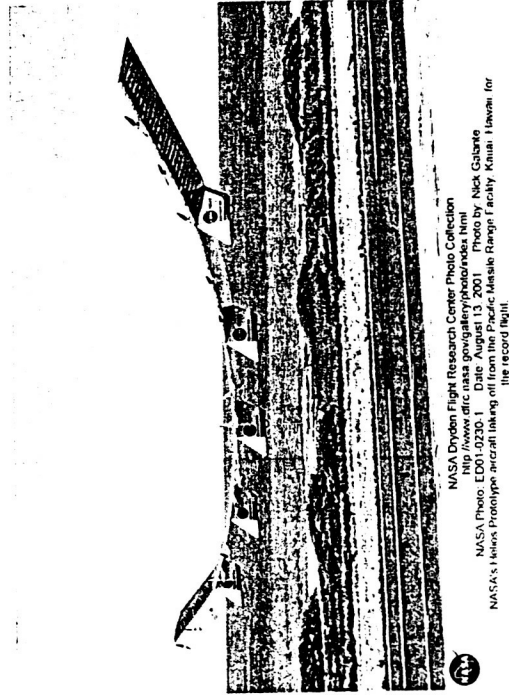
I write...concerning sending 52 student-built “CubeSats” to Mars under the auspices of the NASA Space Grant Program. Let me start by stating that the concept has a significant visionary aspect. It integrates NASA’s Space Science and Education responsibilities into a program that adds substantially to both. If successful, the idea of launching 52 student-built CubeSats to Mars would constitute the first time student-built hardware has been launched beyond Earth orbit.



During the August 9, 2001 test, NASA engineers used a helium balloon to haul the glider to 103,000 feet. At that altitude, the atmosphere is as thin as it is on Mars.

The plane was then dropped. After an initial 13,000-foot plunge, the plane swooped out of its steep dive into stable flight.

Flying for the most part on autopilot, the plane took two hours and 22 minutes to spiral down to a landing in the grass at Oregon's Tillamook Airport. It reached a top speed of Mach .82.



NASA has established two major goals for the Helios Prototype UAV (uninhabited aerial vehicle). The first mission is to reach an altitude of 100,000 ft. on a single day flight with a small payload. It would be a single day mission demonstrating that an aircraft can carry a science instrument to extreme altitudes.

In diminishing sunlight on August 13, 2001, Helios effectively demonstrated this capability when it reached a record altitude of 96,863 feet.

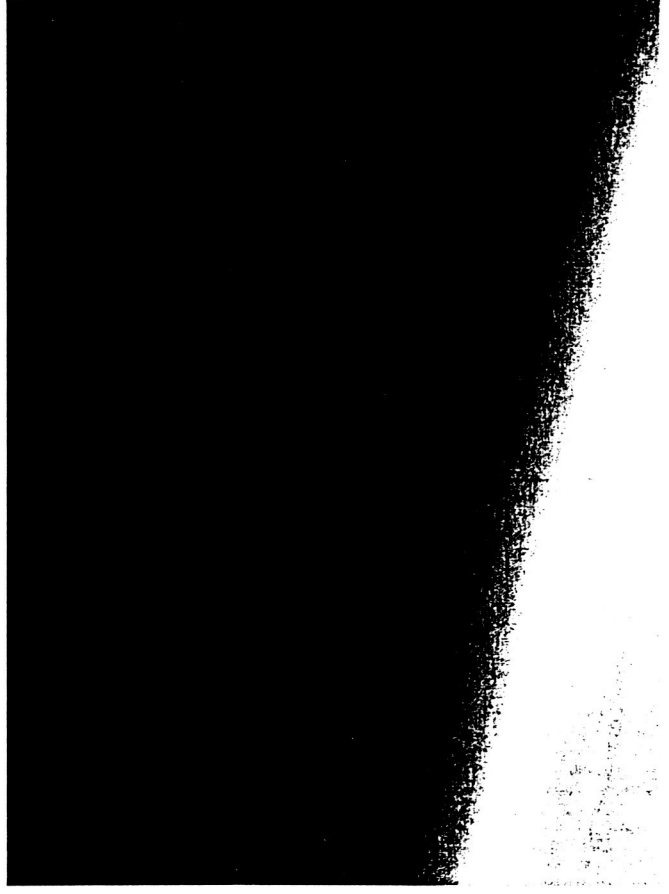
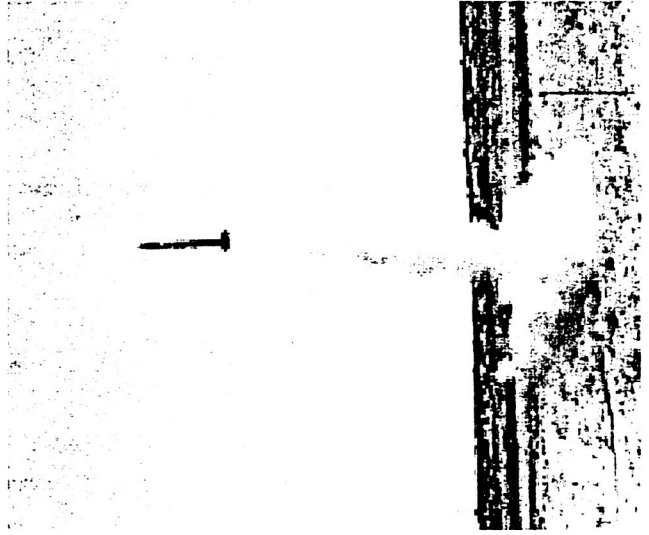
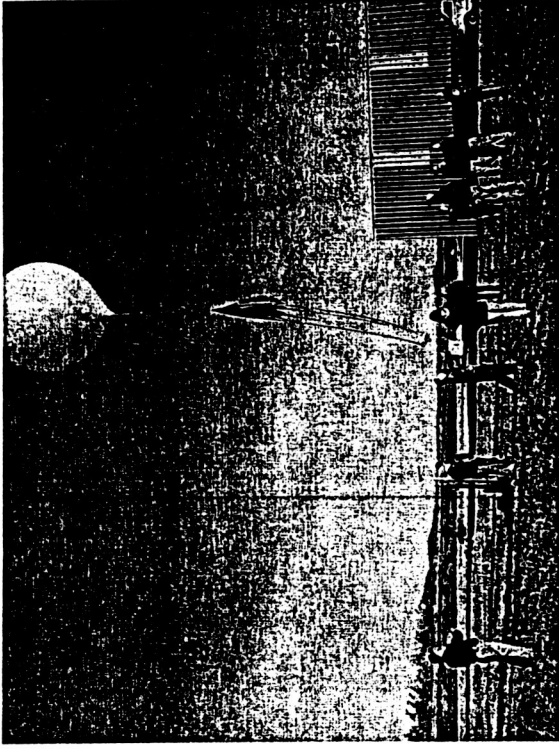
“Crawl” workshop planned

Where: CU (Boulder, CO)

When: Thursday-Saturday, June 20-22

What: detailed, hands-on instruction in how to set up a *“Crawl”* level program on your campus/in your consortium
Thursday-Friday: hands-on hardware workshops, instruction

Saturday: We fly! Balloons, CanSats,



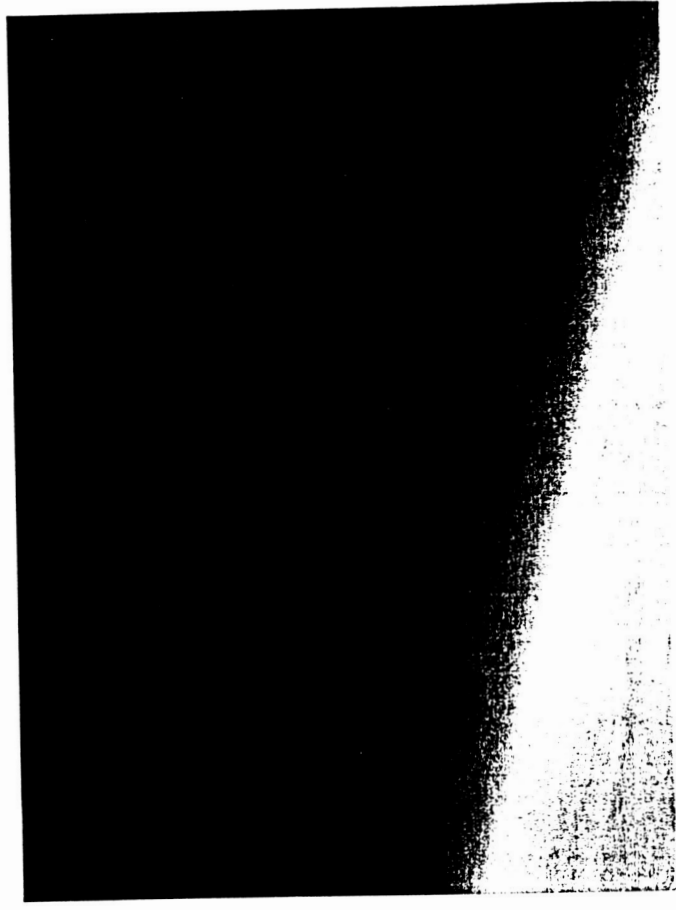
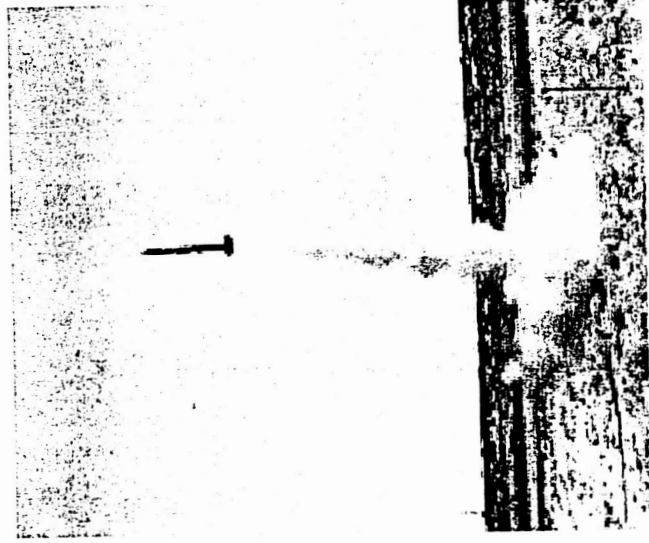
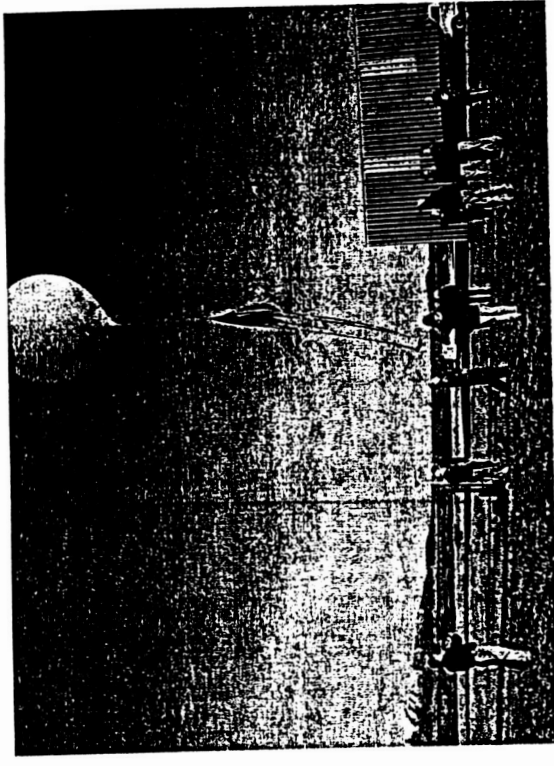
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Idaho Space Grant Education Outreach Opportunities

**Dr. Michael Odell
Dr. Teresa Kennedy
Idaho Space Grant Consortium**

**Aerospace Technology Symposium
March 4, 2002**

Idaho is the only state Space Grant Consortium to be jointly administered by a College of Engineering and College of Education. The Idaho Space Grant Consortium (ISGC) consists of members composed of all Idaho Institutions of Higher Education, Informal Education Agencies (museums, science centers and educational organizations), a research laboratory (Idaho National Engineering Environmental Laboratory), a state park (Bruneau Sand Dunes), a national monument (Craters of the Moon), and many businesses.

Dr. Jean Teasdale is the ISGC Director, Dr. Michael Odell and Dr. Dave Atkinson are the Associate Directors, and Dr. Teresa Kennedy is the NASA Broker/Facilitator for Idaho as well as the Director of the Idaho NASA Educator Resource Center.

Idaho is a Capability Enhancement State. The ISGC provides scholarships and fellowships to students in SMET and science education programs who all volunteer time in K-12 classrooms. The Idaho Space Grant Consortium (ISGC) has strong ties to the scientific, engineering and education communities which results in very unique projects and diverse outreach programs. Information regarding current ISGC programs follow.



NASA Opportunities for Visionary Academics

NOVA is a joint project with the University of Alabama and Fayetteville State University, an HBCU in North Carolina. NOVA has an annual budget of 1.3 million and is listed in the NASA Strategic Plan for education. The network consists of 86 institutions ranging in size

from large Research I institutions to small state colleges. The UI College of Education is the lead institution for technology and online learning for the NOVA network. Idaho has received 1 Million+ in funding.

NOVA seeks to improve science, mathematics, and engineering courses by working with teams of discipline and education faculty in restructuring undergraduate content courses. University teams attend a NOVA workshop to learn about the latest in pedagogy, standards, and technology. Teams submit a Phase I proposal to modify or develop new courses that include NASA's strategic enterprises. Successful NOVA Network institutions are also eligible for Phase II and Phase III funding. Phase II focuses on dissemination while phase III focuses on web-based course delivery. Each year NOVA Network institutions attend an annual meeting at a NASA Center or in Washington DC. NOVA also funds scholarships and fellowships for graduate and undergraduate students. There have been 23 NOVA fellows since 1997. For more information visit <http://education.nasa.gov/nova>.

There are two spin-off projects from NOVA:

NOVA ESS, a three-year project (\$100,000) to evaluate a new online learning model "distributed teaching". NASA's COTF's Earth Systems Science course is being utilized as the medium for the study. The University of Idaho is the lead institution on this project partnering with Kansas State University and the University of Alabama.

NOVA-MUSPIN is a two-year project to disseminate the NOVA model to minority institutions (\$16,000).



The Lifelong Learning Rediscovery Project: L³

The L³ project is a five year \$3 million dollar project to create an innovative online environment for the general public. It is also charged with teacher preparation in the innovative use of technology as well as creation and dissemination of K-12 curriculum.

The project is administered by the ISGC. Other partners include Wheeling Jesuit University and the University of Montana. The project utilizes web-based learning environments for information, teacher training and student projects. The theme is rediscovery of the past 200 years and into the future focusing on the Lewis and Clark Trail and future exploration of Mars.



NASA Education Workshops

ISGC and the Idaho Virtual Campus (IVC) facilitate the NASA Education Workshops program. NEW is a two-week summer training experience at NASA Centers for teachers. The IVC facilitates the course work for workshops held at all NASA centers. For more information visit <http://ivc.uidaho.edu/nasa/>



Palouse Discovery Science Center

ISGC was directly involved in the creation of the Palouse Science Discovery Center and continues to support outreach programs to benefit the center.



Windows on the Universe

WOTU is a three-year training and outreach project to disseminate NASA research on the Palouse. This project is a partnership with ISGC, the Palouse Discovery Science Center, Schweitzer Engineering, First Step Research and area school districts in Idaho and Washington. Over 3000 children, 150 teachers, and 50 preservice teachers have participated in Windows Week activities. Funding of \$20,000 has supported this project.

Pathway to Mars

Pathway to Mars is a 2-year joint project between the ISGC and the Rocky Mountain Space Grant consortium to hold summer institutes for teachers to investigate the complexities of future travel to Mars. \$20,000 in Eisenhower funding helped to sustain this project.

Teaching Astronomy to Children

The TEACH program is held each summer to train teachers in astronomy. Over \$250,000 in state Eisenhower funds have supported this project since 1997. This project is a collaboration between Electrical Engineering and Education.



Constructing Physics Understanding

CPU is a training program to help elementary teachers learn physics and assist secondary teachers in implementing innovative curriculum and pedagogy. CPU is funded by NSF and San Diego State University. Since 1997, the UI College of Education has received \$120,000 from CPU and matching Eisenhower Grant Funds. For more information visit <http://cpuproject.sdsu.edu/CPU/>



Global Learning and Observations to Benefit the Environment

GLOBE is a program to enable children to do "real science" by monitoring their local environment. Children collect local data and submit that information via the Internet to scientists who use the data for research. Students can view their data as visualizations and compare to remote sensing data taken from LandSat. There are 97 countries participating with GLOBE and more than 15,000 schools worldwide. The Idaho Space Grant Consortium partners with the College of Education, the Institute for Mathematics, Interactive Technology and Science (IMITS), and the Center for Evaluation Research and Public Service (CERPS) to administer the Idaho GLOBE Partnership. The UI team has

trained teachers in Idaho as well as Washington, Oregon, California, Montana, Iowa, Missouri, Texas, Florida, and Pennsylvania. They have also trained teachers in Africa, Spain, Mexico, Costa Rica and Canada. The University of Idaho College of Education has trained over 500 GLOBE teachers in the State of Idaho, partnered with 7 school districts and several private schools to implement GLOBE statewide. Nationally, Idaho has the largest number (127) of participating GLOBE schools within one state. Funding for Idaho GLOBE has exceeded 100K since 1997.

For more information you can visit the Idaho GLOBE website at <http://globe.ed.uidaho.edu/globe> or the national GLOBE website at <http://www.globe.gov>.



Inland NW Science Curriculum Dissemination HUB

The Educational Development Corporation with a grant from NSF has chosen ISGC/CERPS in the College of Education to be a dissemination center for NSF sponsored curriculum projects. This is a three-year training project (\$30,000). For more information visit <http://ivc.uidaho.edu/edc>

EOS: Earth Observing System

The EOS project is a NASA funded subcontract through the University of Montana (\$50,000). ISGC developed an online course in Earth Systems Science Education for preservice teachers. This course has been translated into Spanish.

ISTAR

Idaho EPSCoR is funding a program to provide direct science research experiences for Idaho teachers with University of Idaho scientists. Successful applicants spend eight weeks in the laboratory/field. In addition, they attend content and science education seminars to facilitate the transfer of the research experiences back to their classrooms. (\$24,000). For more information visit <http://ivc.uidaho.edu/istar>

Idaho JEMS

The University of Idaho College of Engineering sponsors the annual Idaho JEMS Summer Workshop for students who have completed their junior or senior year of high school. The focus of the 2-week workshop is to expose students to engineering problems within technical and social contexts, and to encourage them to enroll in college. Students participate in lab exercises, field trips, computer exercises, lectures and hands-on activities in Leadership, Engineering Design, Engineering, Math & Science Modeling, and AutoCAD. Up to 60 participants (30 female students and 30 male students) are accepted into the workshops held each July. Upon successful completion of the workshop, students earn two college credits. This program is self-sustaining. For more information visit

<http://www.uidaho.edu/engr/jems/ToC.html>

Idaho Quest Idaho QUEST Summer Camp

The annual QUEST summer camp for 6-8th grade GT students focuses on science and technology and is a recruiting tool for the university. NASA strategic missions are highlighted. This program is self-sustaining. For more information visit

<http://www.uidaho.edu/ed/quest>



IdahoTECH: The Mars Rover Challenge

Idaho TECH has been designed to help meet the National Science Education Standards laid out by the National Research Council (NRC) for students in grades 5-8. The goals are to facilitate abilities in technological design and to promote basic understandings about science and technology. In IdahoTECH, these goals are being actively pursued through group collaboration, the use and promotion of the engineering design process, and the clear communication of the design process to others. IdahoTECH includes

parents, teachers, and students in a meaningful, active educational activity involving the design and construction of a Mars rover that undergoes rover testing at the IdahoTECH Preliminary Design Competitions (PDC). This program is self-sustaining. For more information visit <http://www.uidaho.edu/idahotech/>

OTHER PROJECTS

The ISGC is always represented at the Idaho Science Teachers Association Conference and exhibits each year. ISGC personnel also serve on the board of the Idaho Science Teachers Association and served on the Idaho Exiting Standards Science Subcommittee. The ISGC also contributes to a variety of projects including the Idaho Division of Aeronautics annual teacher aviation workshops, the Idaho Mobile Space Station designed by a former Christa McAuliffe Fellow, and the Discovery center K-12 visitation program.

Due to the steady increase in the Hispanic population of the northwest, the ISGC is presently assembling NASA materials that have been translated into other languages and adding to this database by translating many other NASA educational materials into the Spanish language in order to better serve K-12 students in the State of Idaho and surrounding states. For more information about ISGC visit

[**http://uidaho.edu/nasa_isgc**](http://uidaho.edu/nasa_isgc)

[**http://www.uidaho.edu/ed/imtc/nasa_rerc/**](http://www.uidaho.edu/ed/imtc/nasa_rerc/)

Technology for the Improvement of General Aviation Security: A Needs Assessment

Michaela M. Schaaf
University of Nebraska at Omaha

Introduction

Aviation and aviation security in the United States have traditionally focused on commercial airlines and those airports which they serve. As noted by the U.S. General Accounting Office (GAO), “. . . the booming growth in scheduled commercial airline traffic has tended to obscure developments in another part of the aviation industry – general aviation” (2001, p. 2). Accordingly, resources for aviation and aviation security were allocated based on this trend. Federal aviation security regulations, such as the former Federal Aviation Regulations Part 107 and 108, focused on the commercial sector of the air transport system. However, due to the attacks of September 11, 2001, the focus of aviation security has broadened to include general aviation.

General Aviation - A Missed Target?

Loosely defined, general aviation is that which is not military nor scheduled airlines. General aviation is pervasive in the United States. It accounts for three of every four takeoffs and landings in the U.S., and the fleet is comprised of approximately 219,000 active aircraft (U.S. General Accounting Office [GAO], 2001). General aviation airports are also widespread. “There are approximately 13,000 private-use general aviation airports and 4,800 public-use general aviation airports in the United States” (GAO, 2001, p. 15). About 2,500 of these public-use airports are included in the FAA’s National Plan of Integrated Airport Systems. This plan “identifies airports that are significant to national air transportation and to which FAA allocates funding for infrastructure development” (GAO, 2001, p. 3).

Secretary of Transportation Norm Mineta stated, “General aviation is a critical component of the Nation’s transportation system” (2001, p. 5). Its importance to the nation, socially and economically, impacts directly more than 5,400 communities in the U.S. which rely exclusively on general aviation for their air transportation needs (Mineta, 2001).

The diversity of general aviation is great. It includes corporate aviation, charter flights, flight training, aerial application, sightseeing, and a host of other forms. The airports at which general aviation activity takes place includes those with one aircraft to those with thousands of operations each day. In terms of security perception however, this diversity may be a disadvantage for the general aviation industry as there is no easy solution nor template to secure the wide range of general aviation activities.

Catalyst Events

The history of aviation security involves measures implemented in response to catalyst events. Under this philosophy, general aviation has been excluded from security measures for the most

part. The catalyst events in the history of aviation security center around airliners and large, commercial airports. The aviation security perimeter paralleled the targets of aviation terrorism. The perimeter began with a focus on the aircraft and the passenger cabin, and extended over time to include the ramp and airfield access points, the full terminal, and other off-airport facilities (S. Hoerter, personal communication, May 12, 2000). However, general aviation was often excluded as a focus of this expanding perimeter.

The most recent catalyst events involving the U.S. include hijackings where the passengers were used as hostages in negotiations, explosive devices which were placed aboard aircraft for the purpose of retaliation through the death of innocent passengers, and suicide pilots. These types of activities are not conducive to using general aviation to carry out such horrific acts.

However, general aviation is not immune from breaches in security. On the night of September 11, 1994, Frank Corder, a pilot and truck driver at BWI, used a false name to procure a Cessna 172 from the Hartford County, Maryland Airport (Jennings, Hume, & Compton, 1994; Rochelle, 1994a). At 1:49 a.m., Corder, with a history of mental illness, crashed the single-engine Cessna into the White House, just below the President's bedroom in an apparent suicide. The Secret Service did not detect the aircraft until 14 seconds before it crashed, likely because it did not appear on radar scopes due to its low altitude (Rochelle, 1994a, para. 1). The White House is denoted on airspace charts as restricted airspace. However, the enforcement of restricted airspace was questioned as a result of this crash. "The best they can do is teach all the pilots who fly into the area that this is prohibited airspace . . ." (Rochelle, 1994b, para. 13).

Past aviation terrorist events in the U.S. correlate with increased federal spending in aviation security. Two presidential commissions were established following what appeared to be terrorist events. The bombing of PanAm Flight 103 over Lockerbie, Scotland in December 1988 led to the creation of the President's Commission on Aviation Security and Terrorism. The Commission was tasked with the review and evaluation of "policy options in connection with aviation security" (Executive Order 12686, 1989, para. 2). Some of the final recommendations from the Commission included that the FAA security responsibilities be elevated and that the federal government should manage security at domestic airports (President's Commission on Aviation Security and Terrorism, 1990).

Uncertainty followed the explosion of TWA Flight 800 in 1996, and rumors of terrorism were rampant. In July 1996, President Clinton established a six-month White House Commission on Aviation Safety and Security, also referred to as the Gore Commission. The advisory commission explored measures to improve aviation safety and security (Gore Commission Charter, 1996). The final recommendations of the Gore Commission included positive passenger baggage match on domestic flights ("Federal action urged," 2001) and using government funds to purchase baggage screening equipment for deployment at the nation's airports (Yates, 1997).

Similar to security spending, aviation security enforcement actions taken by the Federal Aviation Administration (FAA) have also followed a catalyst pattern. The FAA enforcement data

illustrates that aviation security enforcements or fines increase after catalyst events. For example, the number of enforcement actions taken increased immediately following the downing of PanAm 103 and the TWA 800 explosion.

Aviation Security – A Broadening Theme

The terrorist attacks of September 11, 2001 and the resulting investigations have had an impact on aviation security in the United States. The investigations revealed that the terrorist pursued flight training at general aviation facilities in the U.S. The resulting attacks caused the security community to broaden their focus beyond the commercial airliners and airports of the past.

To make matters worse for general aviation perception among the public and law enforcement professionals, Charles Bishop, a 15-year old flight training student, crashed a Cessna 172 into a downtown Tampa skyscraper on January 5, 2002 in an apparent copycat suicide. Flight schools, already suffering a 20 percent drop in enrollment since September, worried that an overreaction to the Bishop crash would result in more costly security regulations for general aviation (Rosenberg, Waddell, & Smalley, 2002). AOPA President Phil Boyer defended general aviation in stating, “This was not a breach of security, this was an abuse of trust. . . . An apparently troubled young man who had legitimate access to an aircraft abused the trust of his flight instructor and stole the airplane with tragic results” (AOPA, 2002b, p. 18).

As a result of these events, law enforcement professionals and lawmakers are attempting to strengthen aviation security in the country. One of the areas which has been identified for strengthening is general aviation. “Since September 11 . . . every aspect of aviation, including commercial airlines, on-demand air taxis, private aircraft, flight training, crop dusting, traffic reporting, news helicopters, even balloons were seen as potential threats to national security” (Olcott, 2002).

Background

In the days, weeks, and months which transpired since September 11, 2001, the focus on general aviation as an area for security attention has not wavered. Actions were taken immediately to address the real and perceived threats to the nation’s security that could be achieved through general aviation.

Airspace Restrictions

Substantial actions were taken immediately following the attacks. The FAA shut down the National Airspace System and in a matter of hours. The more than 5,000 airborne aircraft were directed to land at the nearest airport and were grounded without incident (Restrictions on General Aviation, 2001). The airspace remained closed to civilian aircraft until September 13 when additional security measures were implemented. Incrementally, and in cooperation with the National Security Council, the National Airspace System was reopened, flight-by-flight to the air carriers first, and then to other segments of aviation (Restrictions on General Aviation, 2001).

General aviation was not allowed back in the skies at once. It was a slow process that has not yet been restored to pre-9/11 attack status. On September 14, general aviation IFR flights were allowed with restrictions, but not within 25 nautical miles of Washington National Airport nor John F. Kennedy International Airport. News reporting, traffic watch, banner towing, and sightseeing were all still prohibited (Restrictions on General Aviation, 2001). Medivac and other emergency VFR flights were permitted beginning September 19, as well as agricultural operations outside Enhanced Class B Airspace (ECB)¹. On September 21 the airspace was opened to VFR flight training, with restrictions on the size of aircraft inside and outside ECB. On September 28, more than two weeks after the attacks, the airspace was opened to all VFR traffic outside ECB.

By December 19 "the FAA largely restored most of the country to pre-Sept. 11 flight rules, allowing private pilots and any aircraft operating under the FAA's visual flight rules to fly where allowed inside class B airspace. Previously, only general aviation aircraft on an instrument flight plan, student pilots with or without their instructors or pilots who received waivers were allowed to fly there" (Croft, 2001, p. 151).

The closure of airspace was characterized by Secretary of Transportation Norm Mineta as a "crude measure justified then by the unknown nature of the threat posed through [general aviation]" (Mineta, 2001, p. 3).

Closure of Three Washington, D.C.-Area Airports

While the airspace was opened for the most part by December 19, three Washington, D.C.-area airports would remain closed for more than five months after the attacks incurring significant losses. The FBO owner at Potomac Airfield spent hours lobbying to get the airport reopened while he was losing \$45,000 a month during the shut down (Huber, 2002). Due to the close proximity to the nation's capital College Park, Potomac, and Hyde Airports, public-use airports, were considered a threat by the U.S. Secret Service.

In late December, College Park Airport, 7.2 nautical miles east of the Capitol building, was mostly dormant. Manager Lee Schiek was anxious for direction to get the airport open again. "We're begging for someone in the federal government to contact us," he stated (Croft, 2001, p. 151). The airports would eventually be allowed to reopen, but with enhanced security measures for pilots that had been based there for many, many years.

According to Shiek, for this airport to regain operating status, "all pilots were required to be fingerprinted and subjected to an FBI criminal background check. All were then briefed on special ATC procedures and use of Personal Identification Numbers" ("And what some," 2002, para. 1).

On February 23, at 8:35 a.m., pilot Leon Jackler landed a 1975 Grumman Yankee at College

¹ Enhanced Class B Airspace - area within 40-50 miles of most heavily used U.S. airports.

Park. He was the first resident civilian pilot to land there since September 11. The results of the shut down were significant. "College Park, Potomac, and Hyde had lost at least a collective \$1.3 million – and much of their clientele. As of May 2002, only 35 of College Park's previously based 87 aircraft had returned" (Huber, 2002, p. 65).

National Airport Restriction

The reopening of the three public-use general aviation airports was seen as a victory for general aviation. However, as of the end of June 2002, Washington D.C.'s National Airport remained closed to general aviation operations. The airport was closed to all traffic following the attacks of September 11. On October 4, the airport was opened to limited operations by commercial air carriers, but no general aviation traffic was allowed (Restrictions on General Aviation, 2001).

The National Business Aviation Association (NBAA), representing 7,100 business aviation member companies, has strongly lobbied for the airport to remove this restriction. "We are concerned and frustrated that general aviation continues to be denied access to the Nation's airport," said NBAA President Jack Olcott. "Prior to September 11, general aviation operations at DCA accounted for over 60,000 movements, nearly one-third of all operations at the airport" (NBAA, 2002, para. 2). Olcott says the restrictions on general aviation aircraft send two signals: 1) general aviation aircraft owners and operators are less important than the commercial airlines, and 2) America's business leaders cannot be trusted with securing their aircraft (Olcott, 2002, p. 2). As of the writing of this study, the NBAA continues to fight this battle to allow general aviation aircraft access to National Airport once again.

Problem Definition

To adequately address security needs for the general aviation community, it is beneficial to know how fixed base operators (FBOs) perceive general aviation security. Since the September 11 attacks drew more attention to the issue, it would be even more telling to look at data prior to the attacks and compare those results with data following the attacks.

Methodology

The top 50 FBOs in the nation, according to the 1998 *Professional Pilot Magazine*, and their corresponding airport managers were queried in 1998 regarding descriptive information on best practices in general aviation security. A subsequent survey was then administered to the same panel in 2001 to determine if the changed environment as a result of the September 11 attacks had an effect on the previous responses.

The survey was faxed to 86 airport and FBO managers in 1998. The intent of the open-ended questions was to collect descriptive information on best practices in general aviation security, an often overlooked element of aviation security. The survey was again faxed to the sample in 2001 following the terrorist attacks.

The survey responses were coded using the qualitative software EZTEXT. The software allowed

for the separation of airport and FBO manager responses, as well as 1998 and 2001 responses.

Descriptive Results

The descriptive results indicate similarities and differences in general aviation best practices between 1998 and 2001, and between airport and FBO managers. In 1998, 86 surveys were disseminated and 16 completed surveys were returned for a response rate of 18.6 percent. In 2001, 86 surveys were again disseminated and 24 were returned for a response rate of 28 percent. The survey response rates were not substantial enough to conduct statistical tests, however the data do provide interesting descriptive data regarding general aviation security.

Best Practice Responses

This section details those best practices cited by at least five respondents in surveys from both years combined. The frequency as well as specific suggestions made by respondents are included.

Compliance was cited by five respondents as a best practice. Respondent comments included the hiring of security personnel to monitor compliance, the timely response to security requests, and the immediate reporting of problems.

Six respondents had suggestions for best practices regarding vigilance. Suggestions included making security an integral part of the overall business plan and review the status routinely; a formal, airport-wide vigilance program for airport tenants and users; contacting law enforcement when a scenario may be deemed suspicious; and being more inquisitive of all persons.

Communication was cited as a best practice by seven respondents. Suggestions regarding communication included security coordination between airport users and tenants, as well as law enforcement.

Escort procedures was cited as a best practice by eight respondents. Suggestions included all passengers being escorted to the aircraft by a crew member or FBO employee, and not allowing anyone to access the ramp without the escort of an FBO employee (including pilots).

Lighting is a practical and cost efficient best practice cited by eight respondents. In particular, the respondents specified adequate lighting on all areas of the ramp, the FBO operations area, parking areas, and hangars.

Passenger identification was also cited by eight respondents. Suggestions included for charter operators to confirm identities of passengers, screen them, and require them to provide suitable references.

Implementation of a security plan was cited as a best practice by nine respondents. Suggestions for this area included tenant accountability; challenge procedures; consistency with FAA (TSA)

guidelines; implementation of a security task force, similar to a safety committee, that meets regularly to discuss security situations; coordination with the larger airport security program; specific requirements designed for general aviation; and active involvement of FBOs in the security table-top exercises.

Crew identification was cited as a best practice by ten respondents. Suggestions included the issuance of identification codes or passes to arriving flight crews; positive identification checks of pilots and their passengers; FAA establishment of a pilot license with a photo; training FBO employees to ask crew and passengers a series of questions regarding the nature of their activities; establishment of a biometric database for identification; and requiring based pilots to undergo the same background checks as required under the former Part 107.

Employee background checks were suggested by ten respondents. Comments on this best practice included mandating background checks on those with escort privileges.

Security cameras were cited as a best practice by 11 respondents. Suggestions with respect to cameras included monitors of high quality at the squawk box, cameras with live internet feeds, and strategic placement of the cameras to ensure coverage of the entire ramp and operations areas.

Fencing was also cited by 11 respondents as a best practice. Suggestions included fencing which meets the former FAR 107 standard, and perimeter fencing which prevents people and animals from entry and keeps flying debris from the area

Secure entry was cited by 12 respondents. Suggestions for this best practice included installation of combination locks for all doors leading to the hangars and ramp; changing access codes to the electronic gates with an accurate log of names and addresses for dissemination; changing all lock codes frequently; implementing biometric access control; requiring all gates with airfield access to automatically close and lock; use gate cards which record time, date, and identification of those that enter; and utilization of an intercom system to monitor those that enter the gate.

Vehicle identification was also cited as a best practice by 12 respondents. Suggestions for this best practice included requiring all vehicles on the ramp to have passes; restricting private and rental vehicles from the ramp, including storage; creating guard posts for vehicular entry; requiring service vehicles to be identified through company vehicle signage; and requiring all vehicles wishing access onto the ramp to be searched by an FBO employee.

Employee identification was cited as a best practice by 15 respondents. This best practice included all persons on the ramp to have an easily recognizable identification media with a photo, restricting badges to access only those areas necessary, and requiring employees to be uniformed.

Seventeen respondents cited law enforcement as a best practice. Suggestions included utilizing

armed off duty police officers or security personnel during peak departure hours, coordination with local and federal law enforcement, and regular 24-hour patrols by local law enforcement.

Employee training was a common best practice, cited by 27 respondents. There were many suggestions for implementation of this best practice, including:

1. Educate staff, including flight instructors, to be alert to suspicious behavior and report it
2. Create a challenge or a "Neighborhood Watch" type program to be aware of who belongs in the area and who doesn't
3. Train employees to quickly identify those with unescorted access to the facility
4. Establish specific guidelines for employee behavior
5. Ensure employees know their responsibilities and train them to ask questions
6. Require individuals with driving or escorting privileges on the ramp to complete an airport driving course regarding safety and security
7. Require staff to watch a training video on how to identify and report suspicious behavior
8. Encourage employee attitudes through positive reinforcement - NOT negative reinforcement

Finally, access control, the most frequently cited best practice, was reported by 33 respondents. Suggestions for this best practice included restricting airport access to aircraft operators and their passengers, limiting and controlling ramp access points, confirming an individual prior to allowing them access to the ramp, coordinating access with and through the airport authority, and changing access codes periodically.

Best Practices Identified by FBOs

The responses were then separated based on the source, airport or FBO manager, and by year. Figure 1 illustrates the concerns of the FBO managers in 1998. FBO managers in 1998 were most concerned with training their employees, installing security cameras, relying on law enforcement patrols, and providing adequate access control.

In 2001, FBO managers were still concerned with access control, although to a larger degree, and employee training (see Figure 2). However, identification measures were also a strong response by FBO managers in various categories (passenger, vehicle, employee, and crew identification). Whereas, in 1998, only employee identification was cited as a best practice.

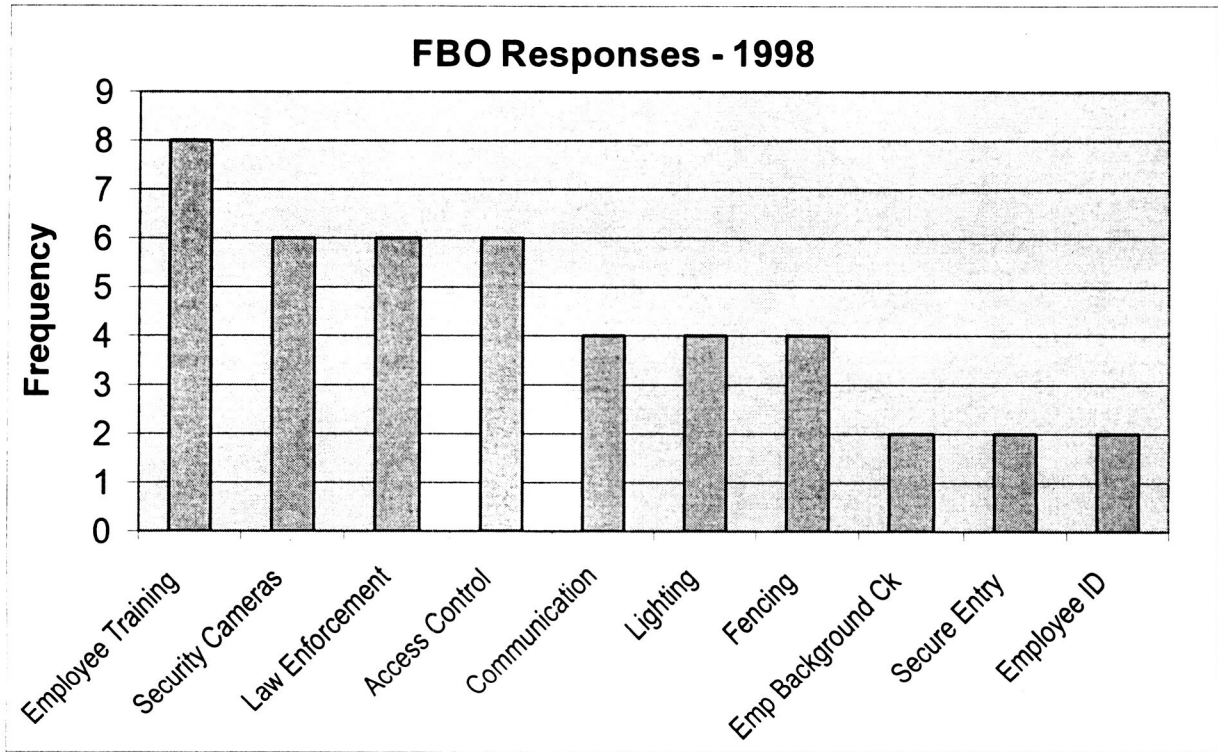


Figure 1. FBO Responses - 1998

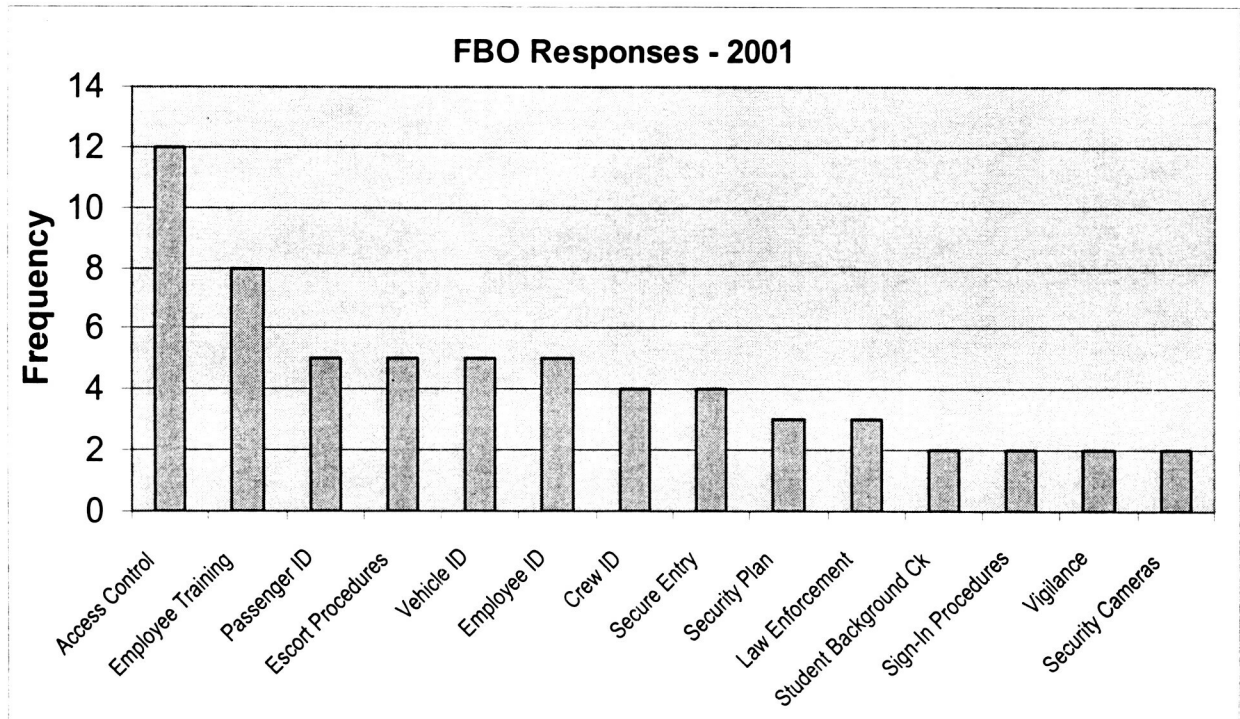


Figure 2. FBO Responses - 2001

Figure 3 provides the responses from the FBO managers in both years on one chart. It illustrates best practices that were cited in 1998 and not in 2001 (communication) and best practices not cited in 1998 that were cited as best practices in 2001 (crew identification, passenger identification, sign-in procedures, student background checks, and vigilance).

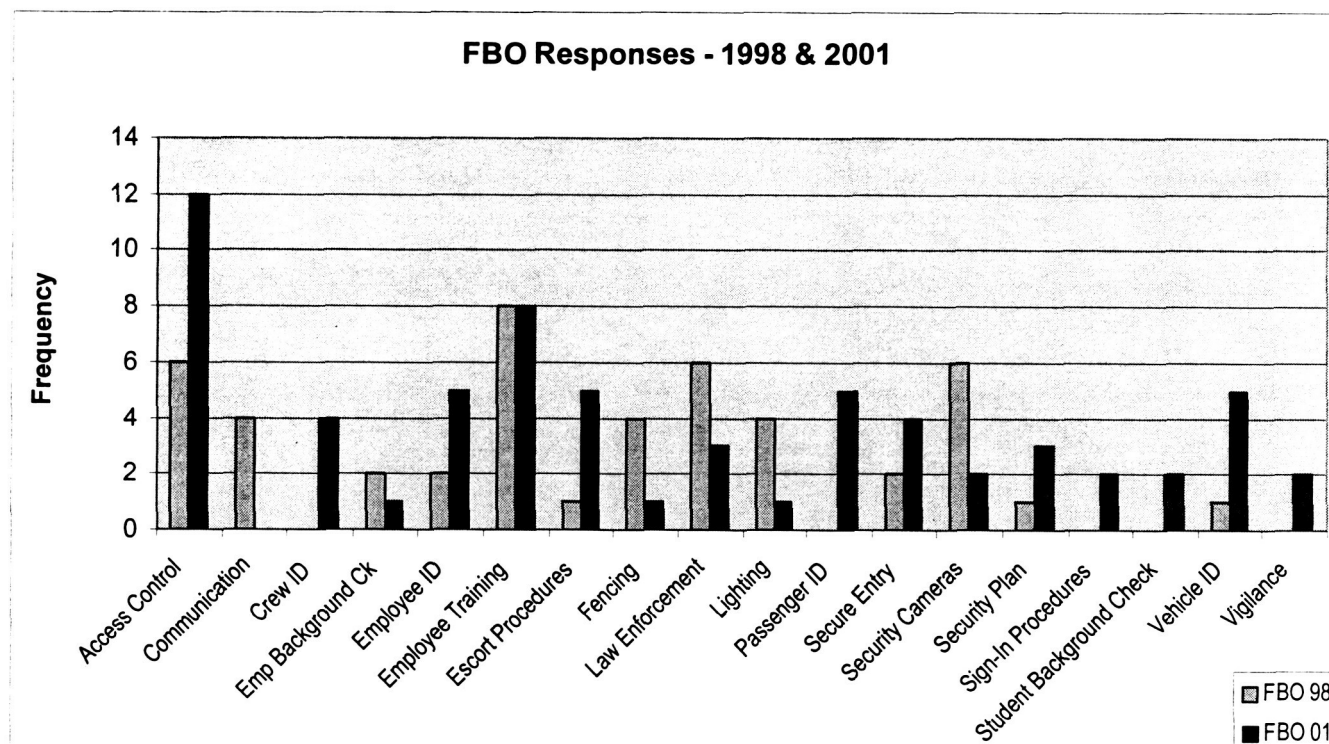


Figure 3. FBO Responses - 1998 & 2001

Best Practices Identified by Airports

General aviation best practices identified by airport managers in 1998 are provided in Figure 4. Airport managers, like FBO managers, cited employee training, access control, and law enforcement patrols as best practices. Unlike FBO managers, airport managers also cited security plans as a best practice in 1998.

In 2001, access control and employee training were the two most frequently cited best practices in general aviation security by airport managers (see Figure 5). Similar to FBO manager responses, in 2001 there were more responses by airport managers regarding identification measures (employee, crew, passenger, vehicle). Interestingly, security plan was not cited as frequently in 2001 as in 1998 by airport managers. Meanwhile, locking the aircraft and key control were best practices not reported in 1998 but best practices cited in 2001.

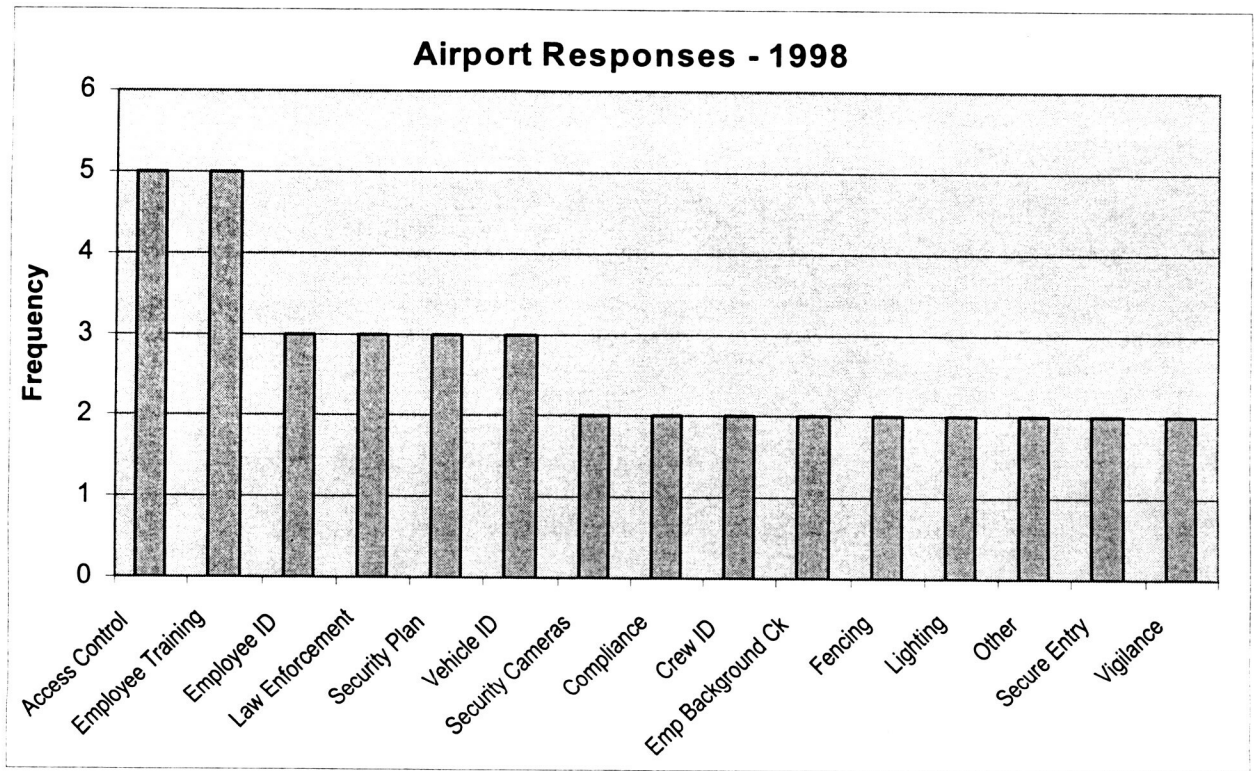


Figure 4. Airport Responses - 1998

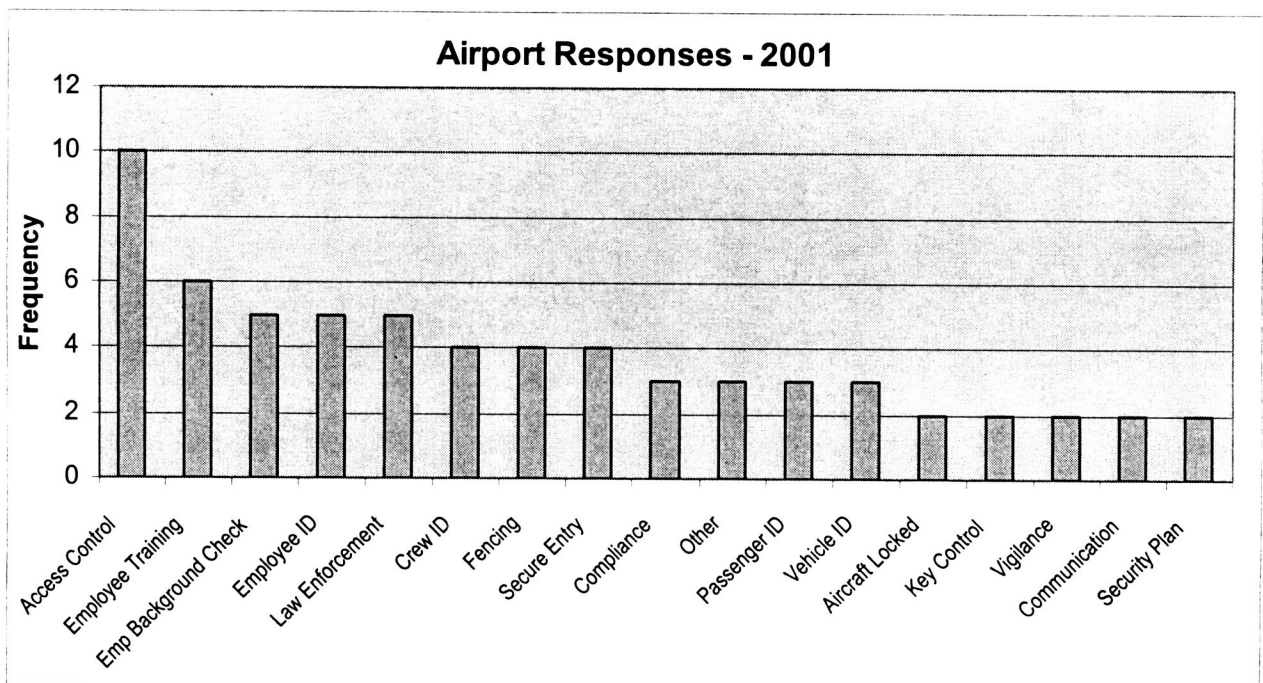


Figure 5. Airport Responses - 2001

The responses of the airport managers from both years are provided on one chart in Figure 6. Only two items saw a decrease in responses from 1998 to 2001: lighting and security cameras. These physical security items were cited in 1998, but not as frequently in 2001. Most other responses saw increases from 1998 to 2001. The largest increases included access control, employee background checks, law enforcement, and passenger identification.

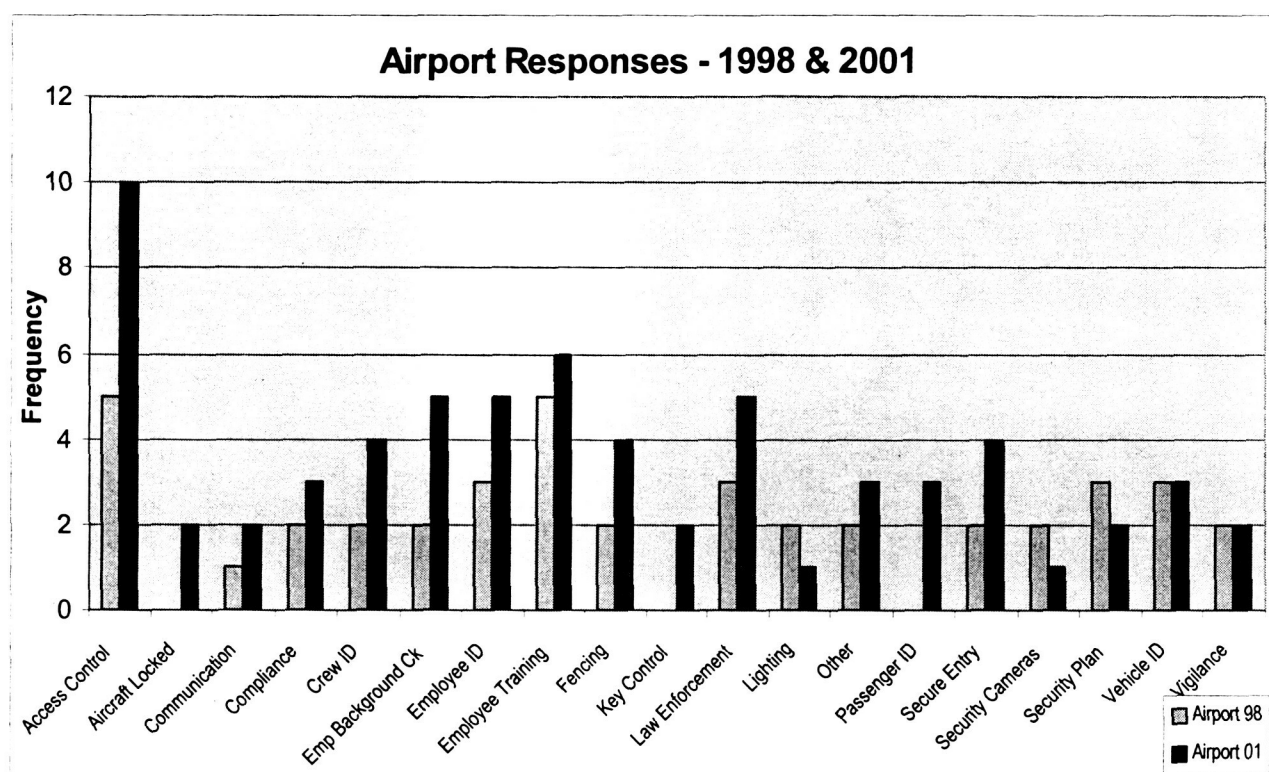


Figure 6. Airport Responses - 1998 & 2001

Comparison of 1998 and 2001 Data

Responses were studied comparing 1998 and 2001 data. In 1998, the most frequent best practices cited included: employee training, access control, law enforcement, security cameras, fencing, and lighting (see Figure 7). Physical security measures such as security cameras, lighting, and fencing were frequently cited.

In 2001, the most frequent best practices cited included: access control, employee training, employee identification, passenger identification, crew identification, secure entry, vehicle identification, and law enforcement (see Figure 8). Identification mediums for security were popular themes in the 2001 responses.

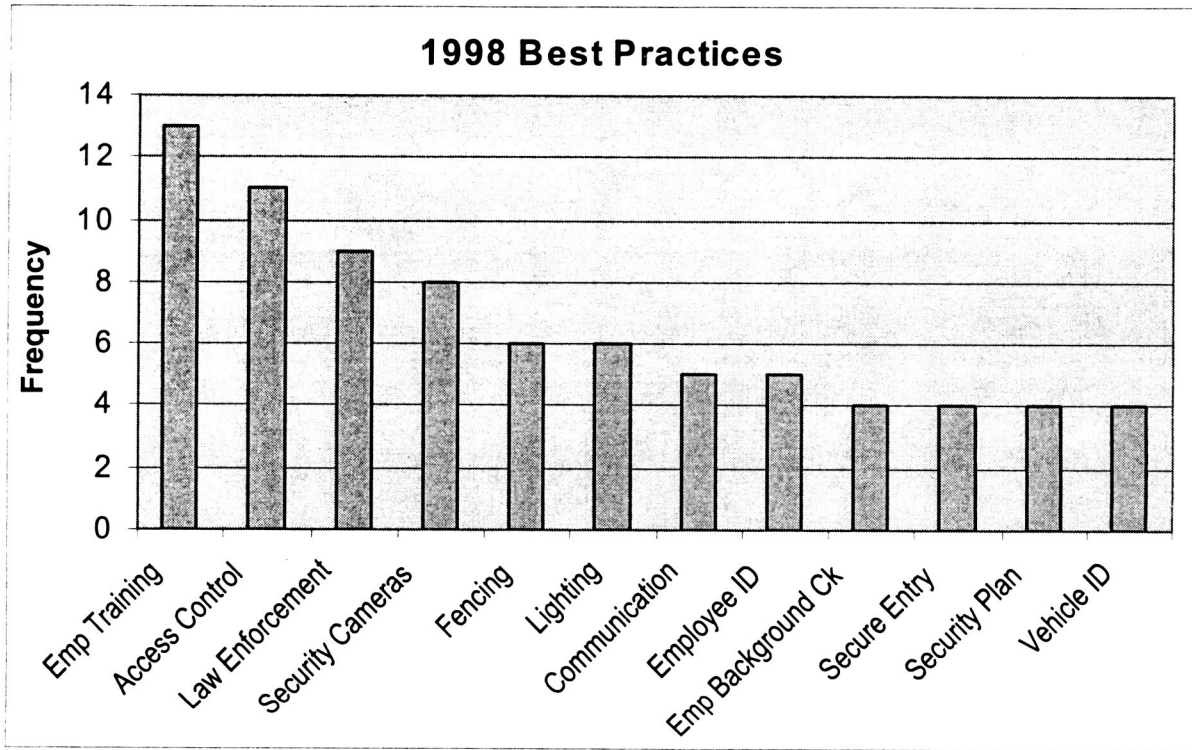


Figure 7. 1998 Best Practices

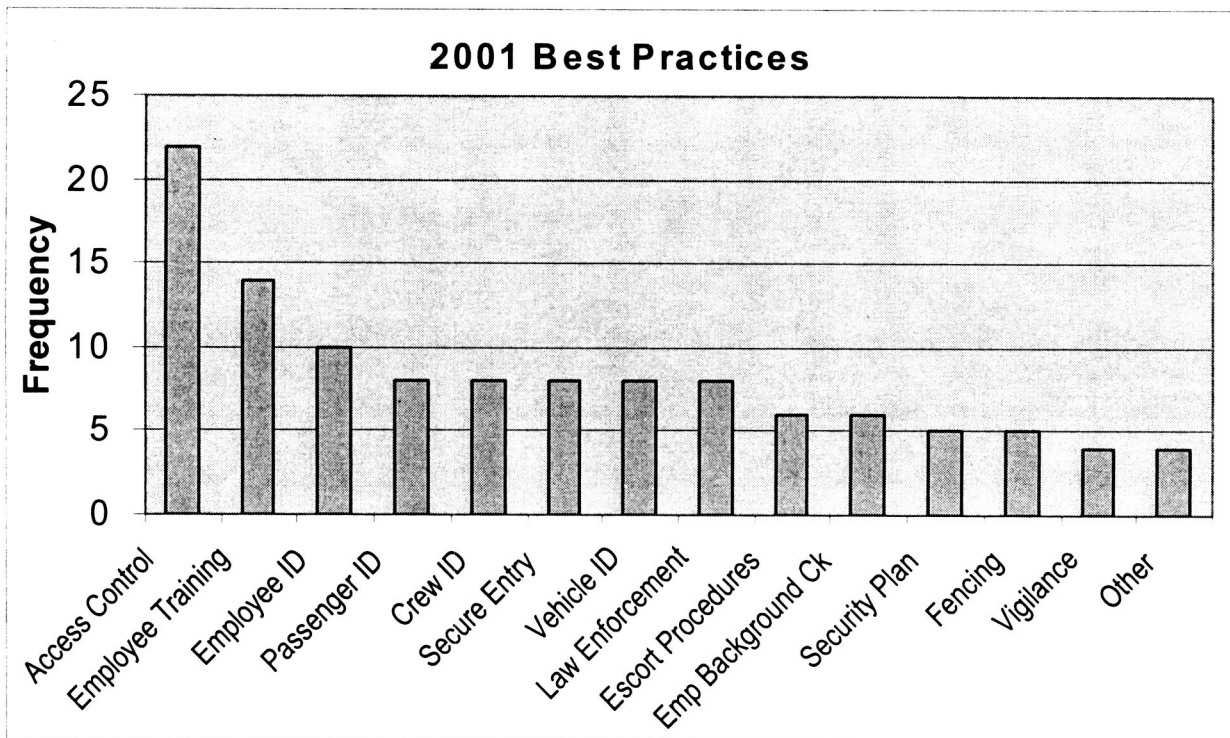


Figure 8. 2001 Best Practices

Figure 9 presents the data for 1998 and 2001 responses together on one chart to compare the changes from time period to the next. Access control, a frequently cited best practice in 1998, saw a substantial increase from 1998 to 2001, the largest increase of any response.

Three of the top responses in 1998 involved physical security measures, none of which made the top five responses in the 2001 survey.

In 1998, no responses were received regarding flight student background checks. While in 2001, three responses included flight student background checks as best practices.

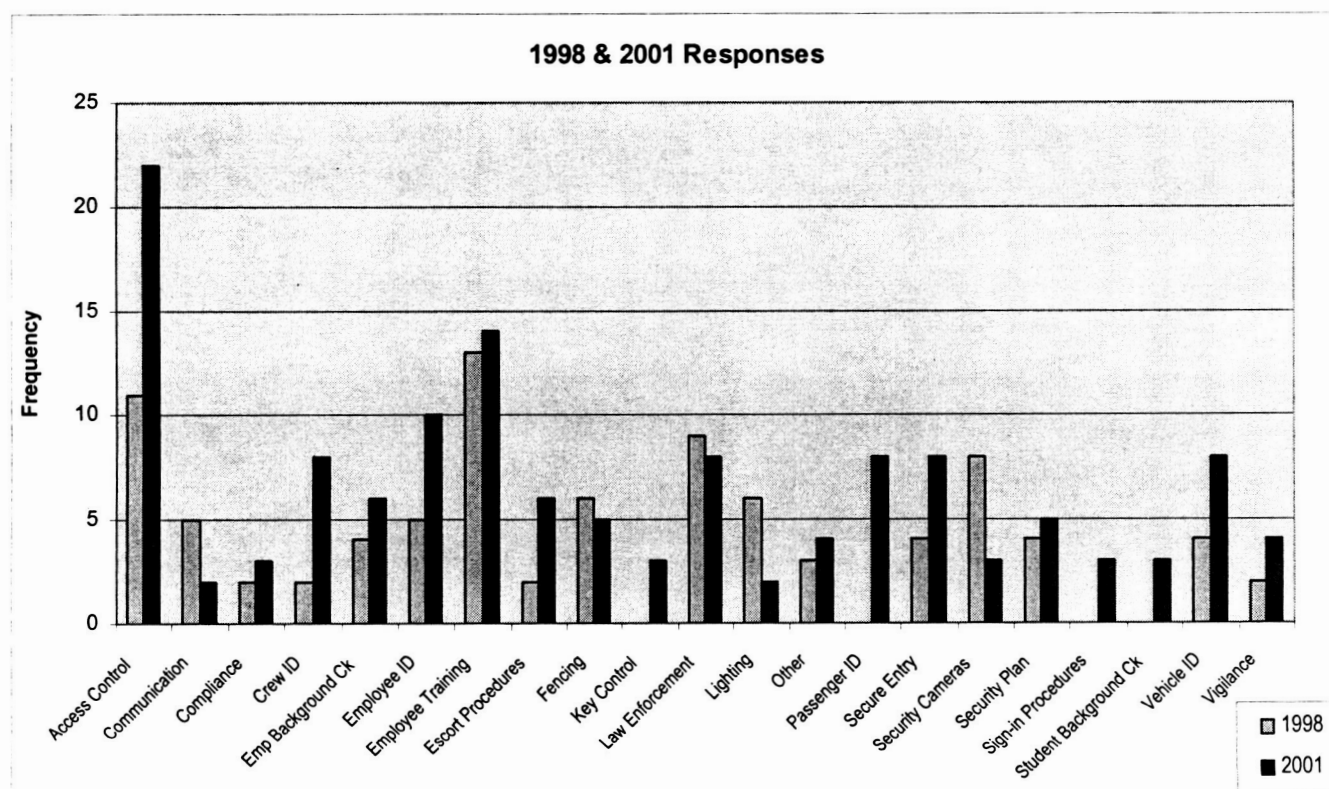


Figure 9. 1998 & 2001 Responses

Comparison of FBO and Airport Manager Data

Two different groups of respondents were queried in the 1998 and 2001 surveys. Figure 10 separates the responses of airport managers and FBO managers to compare different perspectives of general aviation security. Only best practices cited by at least five respondents are included.

Best practices which generated similar response frequencies from both airport and FBO managers included access control, employee identification, fencing, law enforcement, vehicle identification, secure entry, and security plan. Additionally, airport managers favored compliance and employee background checks. Meanwhile, FBO managers favored employee

training, escort procedures, and security cameras.

Overall, access control and employee training each generated the most responses from both groups.

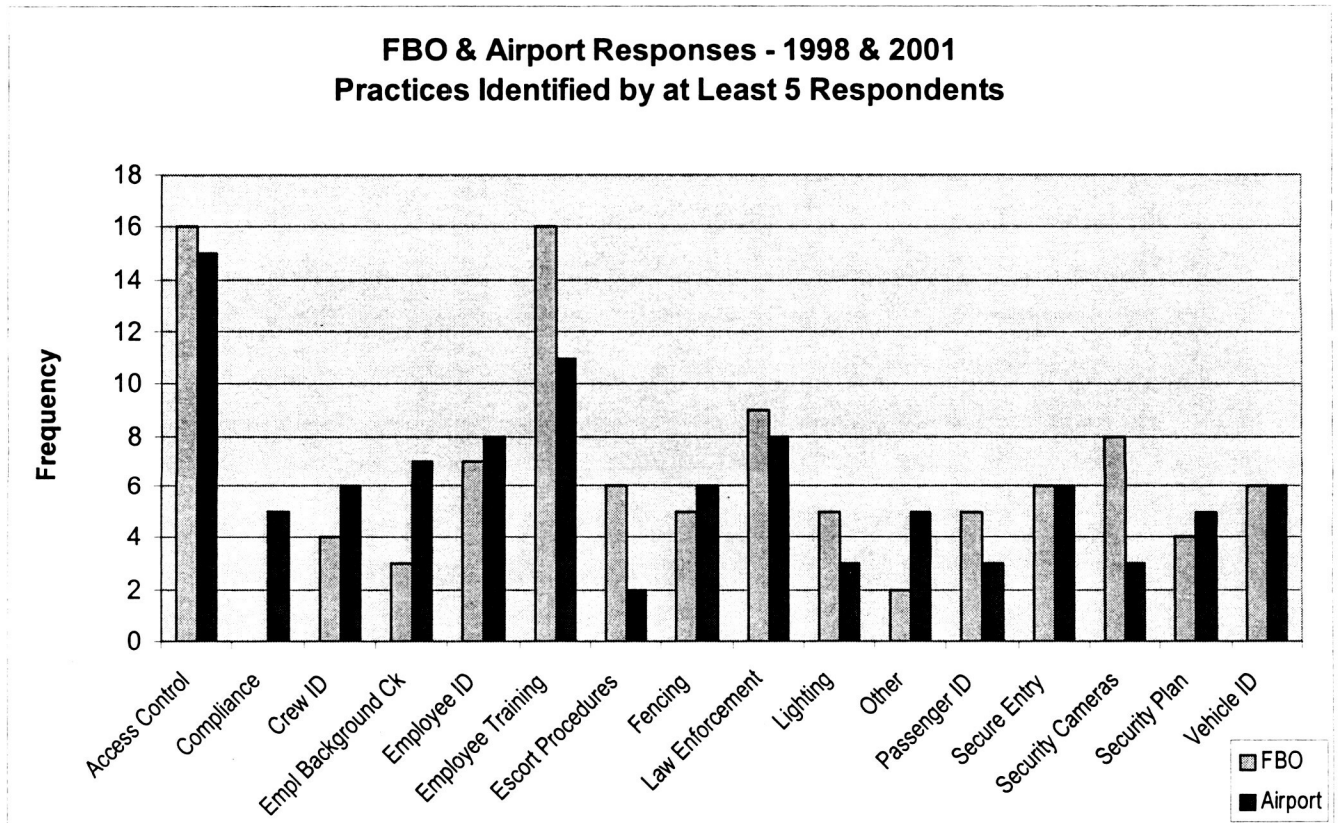


Figure 10. FBO and Airport Responses - 1998 & 2001, Practices Identified by at Least 5 Respondents

Total Responses from 1998 and 2001

The total responses from both years, combining FBO and airport manager responses together is illustrated in Figure 11. Those best practices identified by at least five respondents are shown.

Access control and employee training dominate the combined listing, while other responses are fairly close in range.

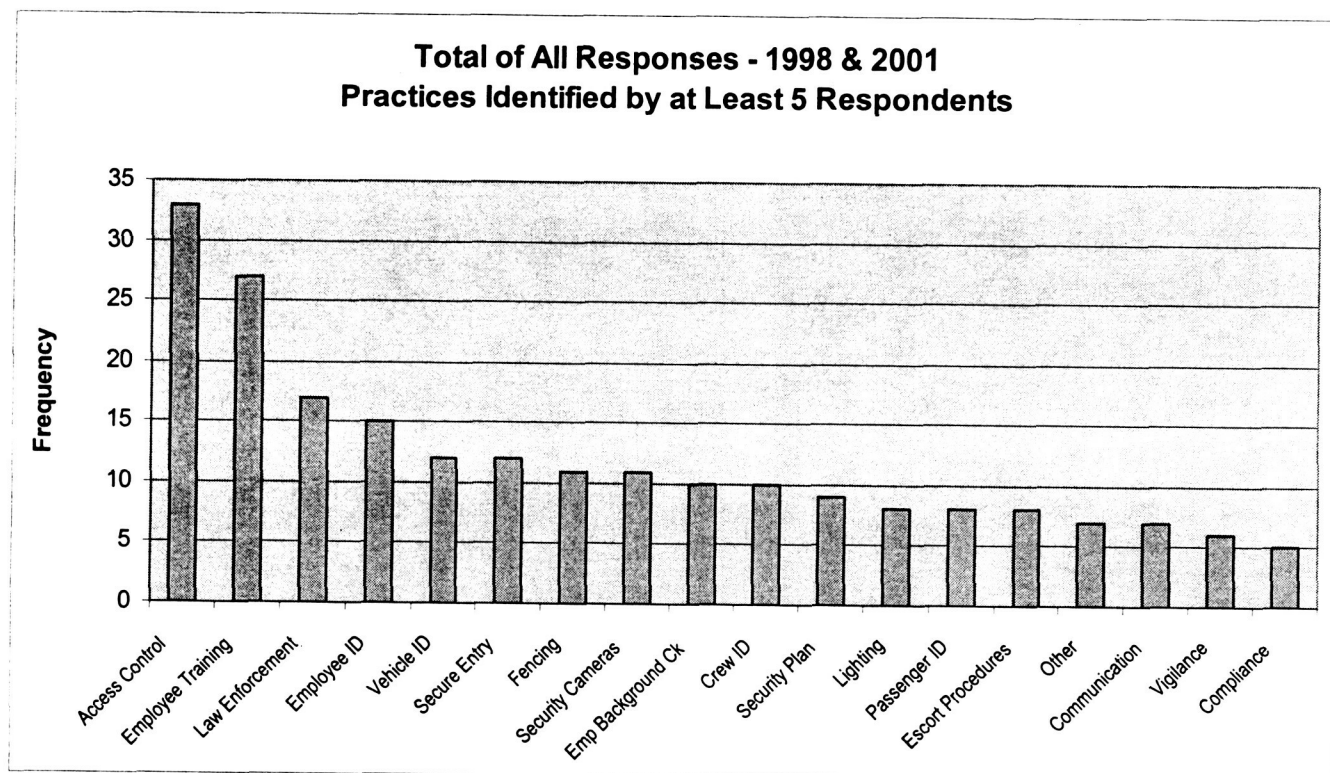


Figure 11. Total of All Responses - 1998 & 2001, Practices Identified by at Least 5 Respondents

Conclusion

General aviation has been identified as an area for potential regulatory action with respect to security concerns. It is important to recognize the diversity of the general aviation industry in such a needs assessment. The best practices cited by those in the industry as a starting point for implementation of new practices.

Further research should be conducted to determine what affordable technological solutions university partnerships, NASA, the FAA, and private industry can contribute to the general aviation sector. Areas of consideration include access control mediums, secure entry, photographic equipment, and identification mediums.

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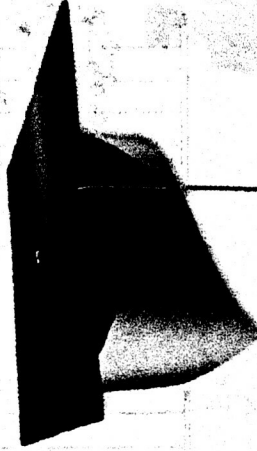
The NASA Aeronautics Blueprint - Toward a Bold New Era of Aviation



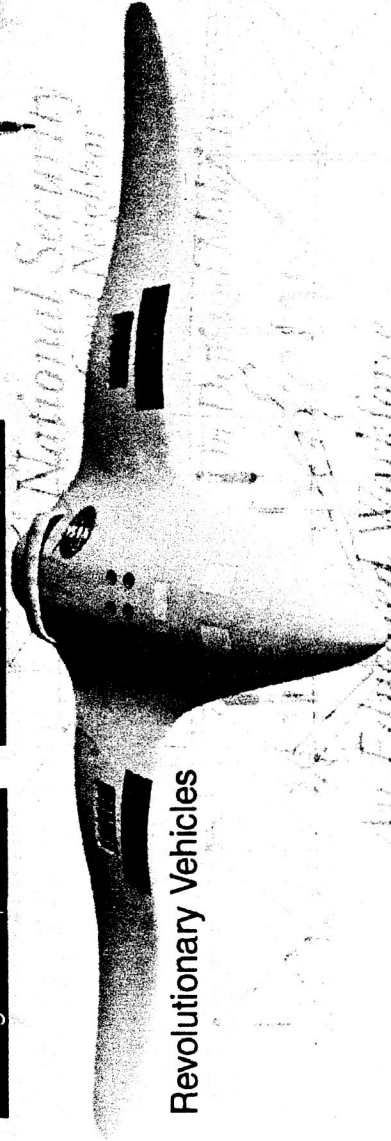
Digital Airspace



Security & Safety



State of the Art
Educated Workforce



Revolutionary Vehicles



Aeronautics

Blueprint

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3.0 State-of-the-Art Educated Workforce

- 3.1 Approach to Education
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- 4.1 Summary
- 4.2 NASA's First Steps to Achieve the Vision



Aeronautics

Blueprint

Executive Summary

- Aviation is crucial to U.S. economic health, national security, and overall quality of life.
- Our Nation is facing serious challenges in aviation.
- NASA's Aeronautics Blueprint outlines the advanced technologies that can help solve today's problems and create a new level of performance and capability in aviation:
 - Advanced concepts for the airspace system
 - Revolutionary vehicles with significantly greater performance
 - New paradigm for safety and security
 - Assured development of the capable workforce of the future
- The cost of inaction is gridlock, constrained mobility, unrealized economic growth, and loss of U.S. aviation leadership.

The Imperative



Aeronautics

Blueprint

Aviation is Critical to the U.S.

Economic Growth

- Productivity
- Global Competition
- Fullest Commercial Use

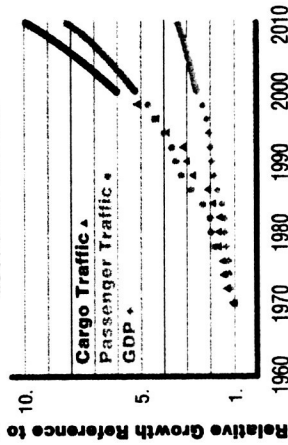
National Security

- Air Superiority
- Global Mobility

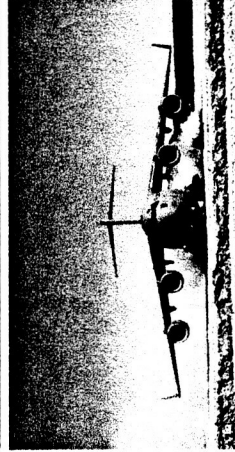
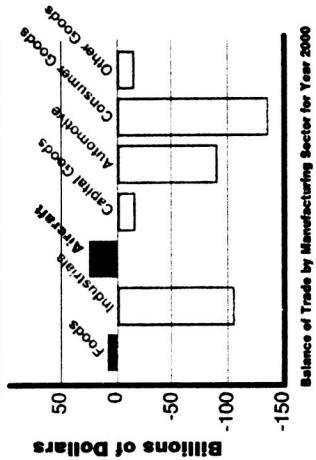
Quality of Life

- Freedom of Movement
- General Welfare

Aviation Contributes and Enables Economic Growth



Aviation Contributes >\$26.7 Billion to Positive U.S. Balance of Trade



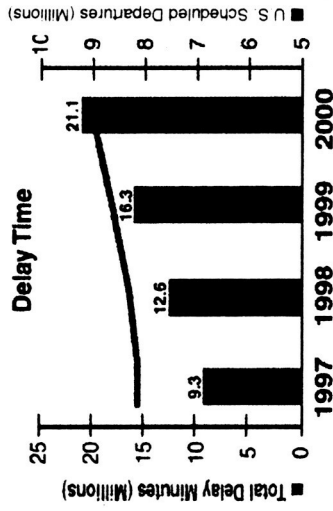


Aeronautics

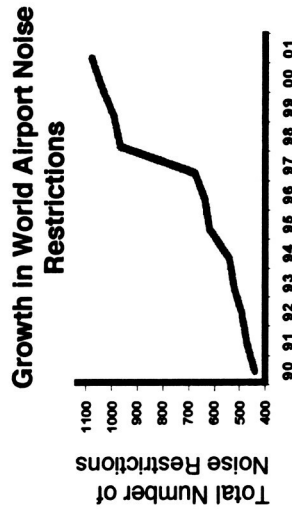
Blueprint

Key Aviation Challenges

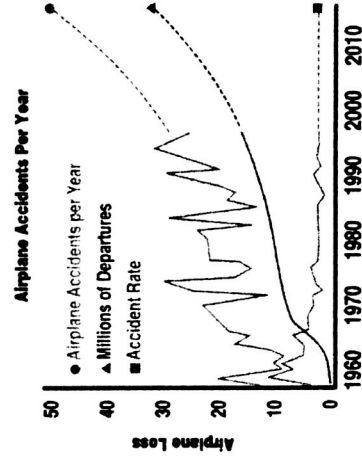
- Limits to capacity - U.S. aviation system is approaching gridlock.



- Noise and emissions are constraints on aviation growth.



- Security and safety must be maintained.





Aeronautics

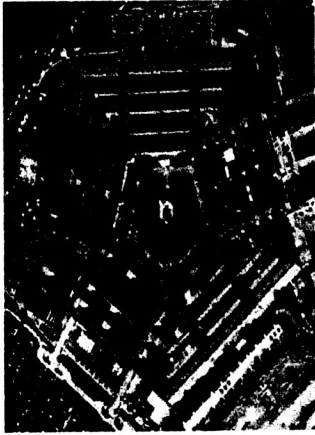
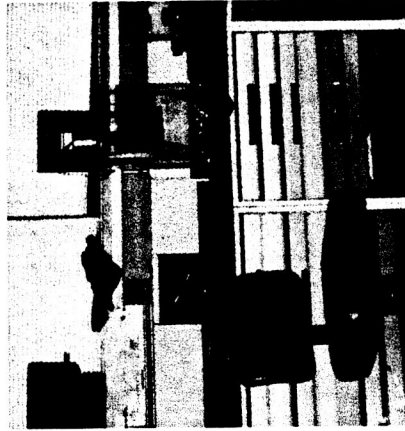
Blueprint

Key Aviation Challenges (Continued)

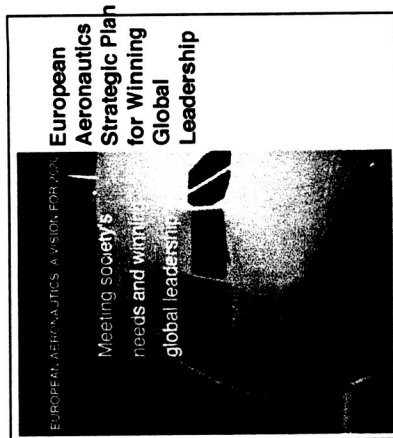
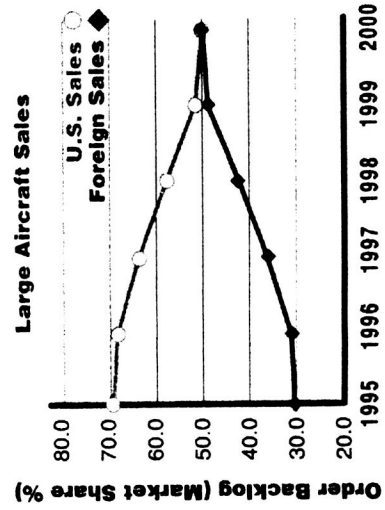
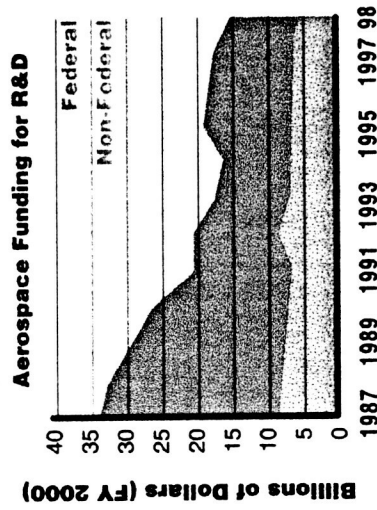
- The changing national security threat demands technical superiority.



- Aerospace R&D investments and skilled workforce are declining.



Courtesy of IKONOS



- The U.S. is losing global market share and leadership.



Role of Government in Aeronautics Research

Government Responsible to Provide:



Air Traffic Operations

- Safe and secure
- Environmentally compatible
- Meet growing demand



Enabling Technology in the National Interest

- Basic research
- High-risk technology
- Unique facilities
- Educated workforce



National Security

- Air superiority
- Technical superiority
- Full-spectrum dominance

■ Technologies flow between civil, military, and commercial applications

■ Need for Government role in aeronautics technology



Ongoing NASA/DoD Collaboration

NASA is collaborating in strategic planning and is providing technical solutions to DoD:

■ DoD Joint Vision 2020



■ Quadrennial Defense Review Report



Aging Aircraft

High-Performance Propulsion

Autonomous Operations

Revolutionary Vehicles

- Safety of flight
- Affordability
- Reduced noise and emissions
- Lightweight, high-strength adaptable structures
- Adaptive controls
- Situational awareness

Reduce Design Cycle Time & Development Tools

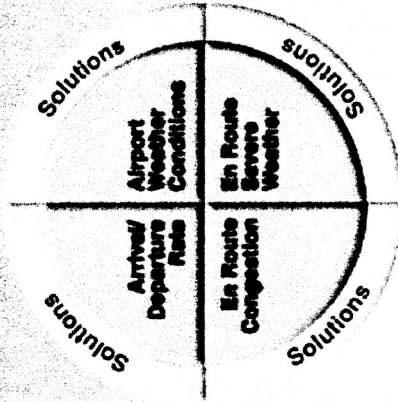
Surface currents
Near Fields
Scattering Image



Ongoing NASA/FAA Collaboration

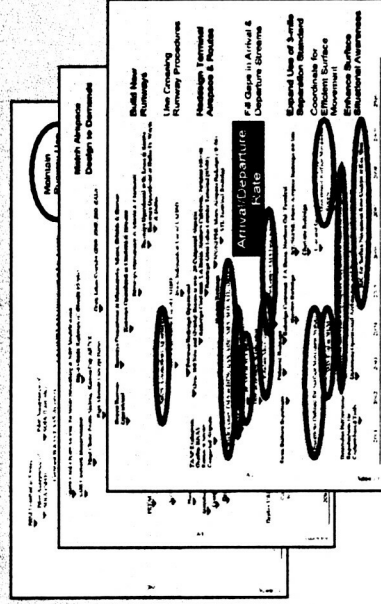
NASA is currently supporting FAA Operational Evolutionary Plan (OEP):

- NASA participated in planning
- NASA is in partnership on critical path



Organization of challenges addressed by OEP

NASA's technology is prominent in the FAA's roadmaps





Aeronautics

Blueprint

The NASA Role

NASA provides enabling technologies, expertise, state-of-the-art facilities, and technology solutions:

Economic Growth

- Productivity
- Global Competition
- Fullest Commercial Use

National Security

- Air Superiority
- Global Mobility

Quality of Life

- Freedom of Movement
- General Welfare





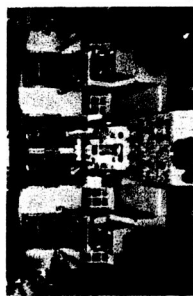
Aeronautics

Blueprint

First Century of Aviation Progress

2012-2013-2014-2015

Technology advances have enabled today's world of aviation . . .



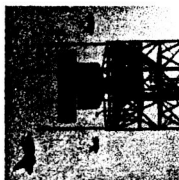
Glass Cockpit



KC-135/707, Jet Age



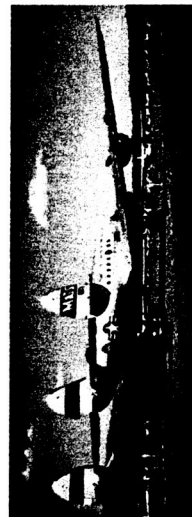
777, Supercritical Wing,
Highly Reliable Engines



Air Traffic Radar



B-47, Swept Wing, Jet
Propulsion



Constellation, Pressurized Cabin, Limit on
Piston Propulsion



DC-3, Riveted Metal Structure,
Retractable Gear



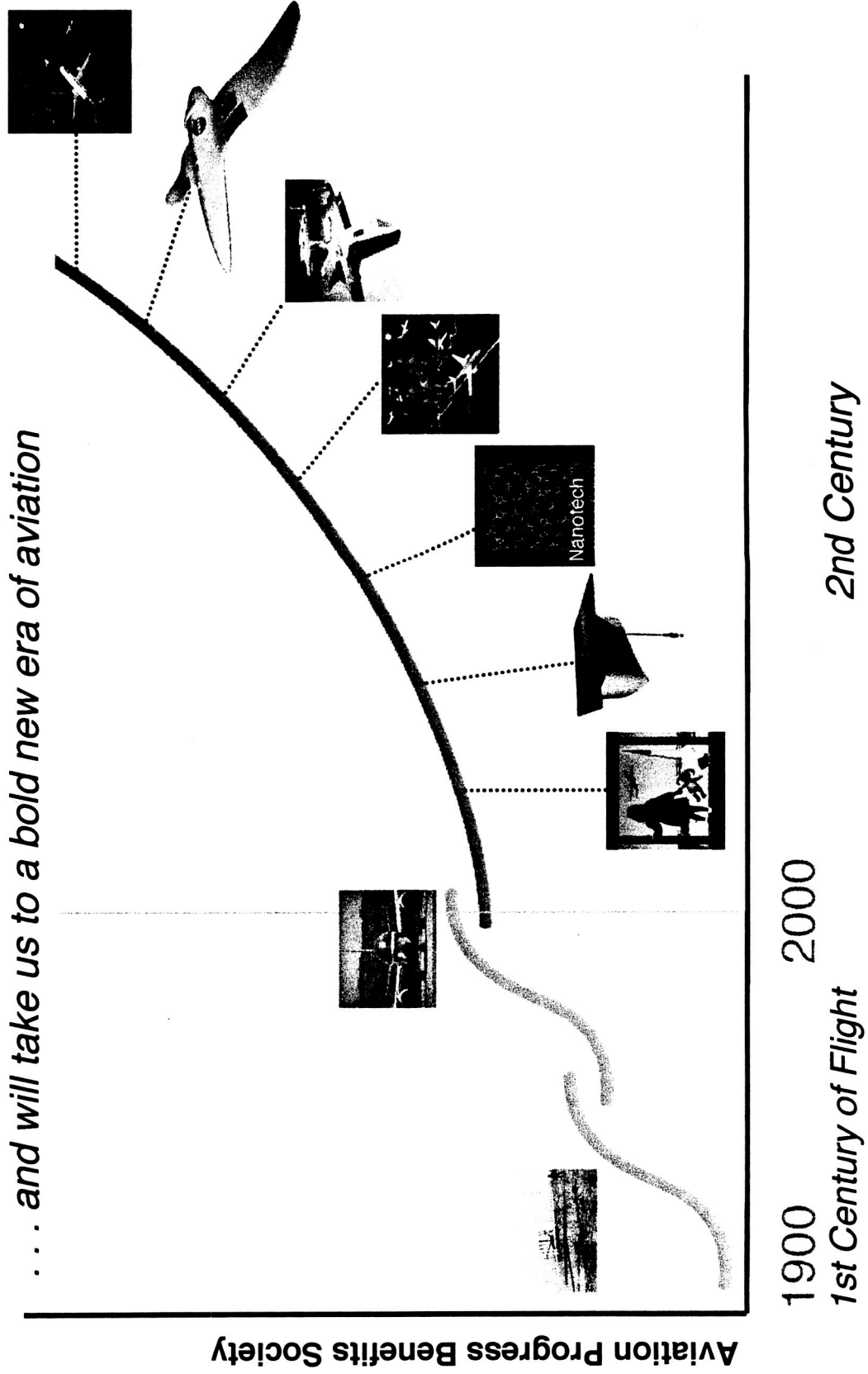
Wright Flyer

1900

1950

2000

Aviation Progress Benefits Society



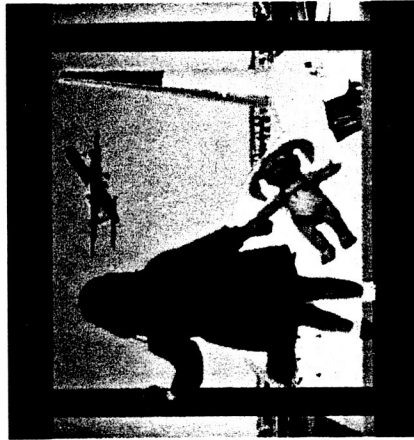
A Bold New Era is Possible



A Bold New Era of Aviation is Possible

Airline	Flight	City	Arrivals	Time	Gate	Remarks
Continental	1006	KCA West		10:15am	B1A	On Time
TWA	5335	Alamogordo		11:45am	A1A	On Time
UNITED	59	New York JFK		12:25	A2	On Time
UNITED	670	Cleveland		11:50am	B5	On Time
DELTA	263	Newark		10:29	B1	On Time
DELTA	9250	Lampa		12:55pm	B1A	On Time
WESTWIND	401	Albany		11:03am	B9	On Time
NORTHWEST	2015	Atlanta		10:14am	B2	On Time
US AIRWAYS	2439	Boston		10:40am	B4	On Time
US AIRWAYS	401	Cincinnati		11:03am	B9	On Time

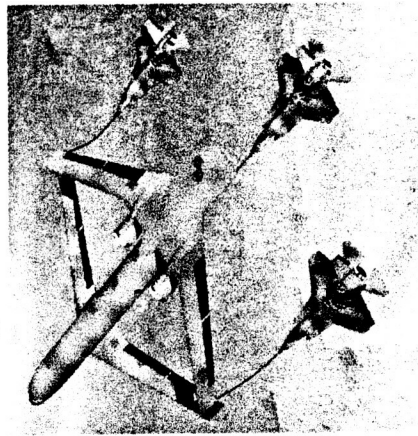
■ On-Time—All the Time



■ Aviation Security and Safety



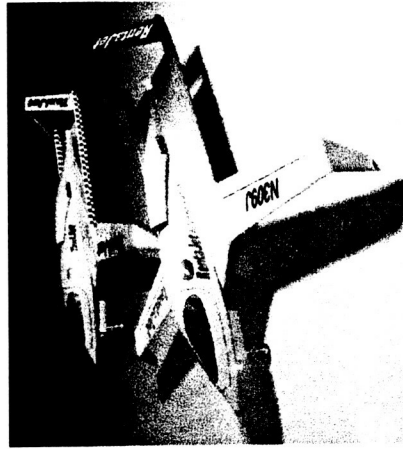
■ Freedom of Mobility, Access to Communities Large and Small



■ Meeting the Changing Threat



■ Clean, Quiet, Good-Neighbor Airports



■ New Choices in Personal Air Transportation



Organization of the Aeronautics Blueprint

The Blueprint has four major elements:

Economic Growth

- Productivity
- Global Competition
- Fullest Commercial Use

National Security

- Air Superiority
- Global Mobility

Quality of Life

- Freedom of Movement
- General Welfare



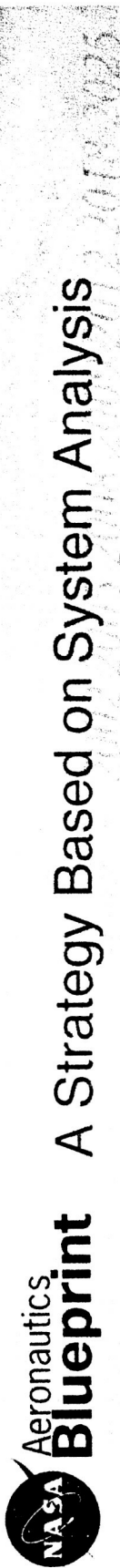
1. The Airspace System

2. Revolutionary Vehicles

3. Security and Safety

4. An Educated Workforce

Toward a Bold New Era of Aviation



A Strategy Based on System Analysis

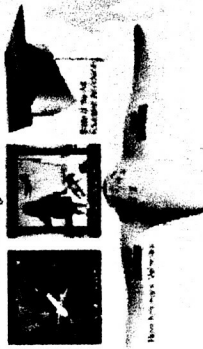
Collaborative Partners



Investment Strategy

Aeronautics Blueprint

Toward a Bold New Era of Aviation



Research and Systems Engineering

- Government, Industry, and Academia collaborations
- Systems engineering
- Defining requirements
- Research & technology development

NASA Research Centers:



Information Technology
Flight Path Monitoring
Simultaneous Operations
High-resolution Weather
Nanotechnology
Morphing Airframe
General Aviation
Precision Navigation
Advanced Sensors
Propulsion
High-Flow Airports
Streaming Flight Recorder
Refuse-to-Crash
Synthetic Vision
Aging Aircraft

National Goals

- Economic Growth**
 - Productivity
 - Global Competition
 - Fullest Commercial Use
- National Security**
 - Air Superiority
 - Global Mobility
- Quality of Life**
 - Freedom of Mobility
 - General Welfare



Aeronautics

Blueprint

The Airspace System

Today's Challenges:

- Overcome reduced throughput in bad weather
- Eliminate en route congestion and the "domino effect" throughout the system
- Keep pace with demand for arrival and departures at benchmark airports*
- Increase situational awareness in the system



Precise Weather



Traffic Optimization



High-Flow Airports



Precision Navigation

- **High-resolution weather**
 - Precise forecasts
 - Precise wake vortex knowledge
- **System-level traffic flows optimization**
 - Separation assurance for complex traffic flows
- **High-flow airports**
 - No gaps in arrival and departure streams
 - Efficient surface movement and rapid reconfiguration
- **Communication, navigation, and surveillance**
 - High-bandwidth and reliable data transmission
 - Precision navigation
 - System wide coverage



Aeronautics

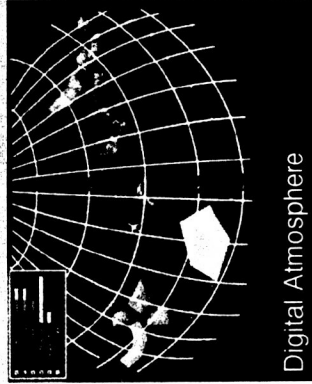
Blueprint

The Airspace System-Weather



Today's Challenges:

- Reduce disruptions of en route traffic due to bad weather
- Eliminate delays in terminal area airspace
 - Efficiently manage terminal area traffic flow
 - Understand wake vortex movement and dissipation



Digital Atmosphere

■ Complete digital knowledge of the en route atmosphere

- Precision forecasts
- Sensors
- Worldwide measurements
- Data processing
- Information dissemination



Simultaneous Takeoff & Landing

■ Precise local weather forecasts integrated with airport operations

- Reliable prediction and conformation of wake vortices integrated with atmospheric conditions



Wake Vortex Knowledge



Aeronautics

Blueprint

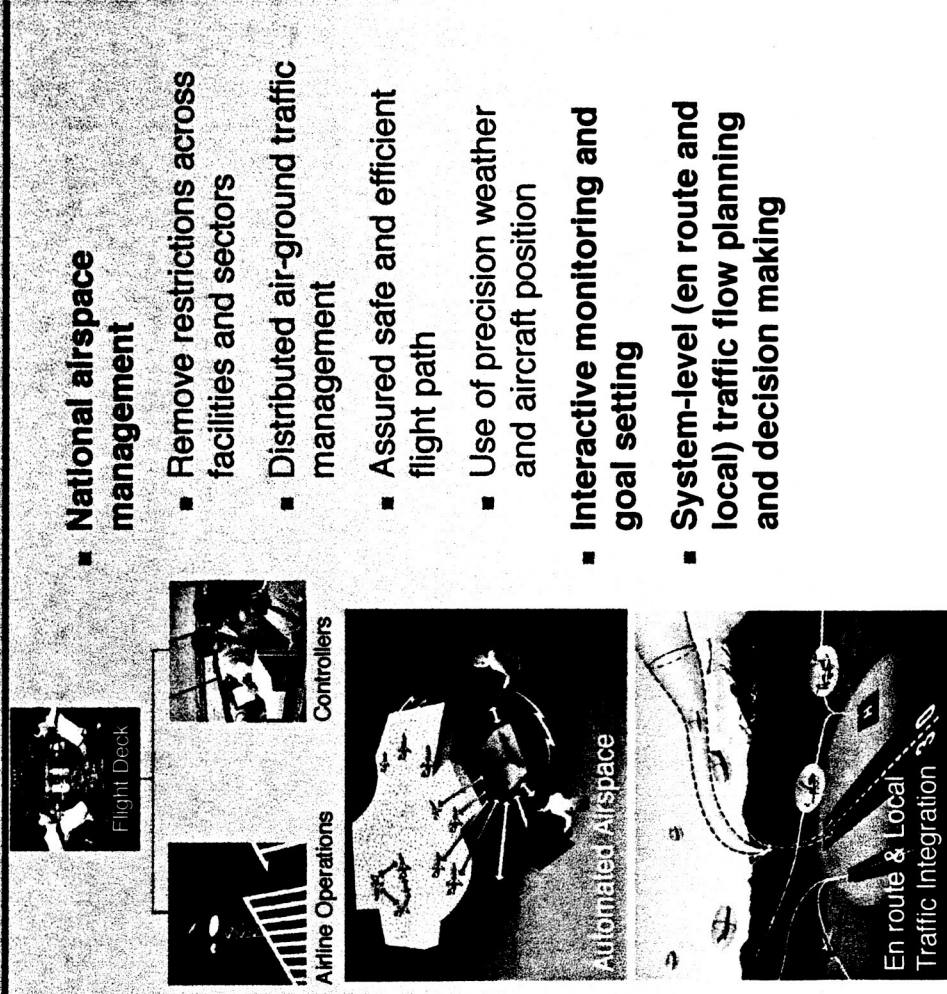
The Airspace System—Traffic Optimization



Today's Challenges:

- Eliminate the air traffic “domino effect” across the National Airspace System
 - Geographic “choke points”
 - Limited airspace/sector flexibility
- Increase airline flexibility to manage contingencies
- Minimize congestion in complex traffic situations

Technology Solutions





Aeronautics

Blueprint

The Airspace System—High-Flow Airports



Today's Challenges:

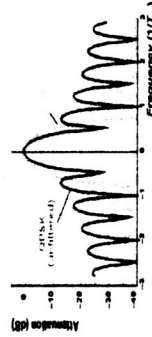
- Eliminate gaps in arrival/departure streams.
- Increase airport operations in bad weather.
 - Single-runway use limits
 - Parallel-runway use limits
- Enable rapid reconfiguration of runways.
- Integrate short-haul aircraft into airport operations.
- Exploit 5,000 underutilized public airports.



- Integrated arrival, departure, and surface decision-support tools
 - Precision spacing and merging
 - Optimized surface operations
- All-weather situational awareness and response
 - Synthetic vision
 - Computer-assisted air and ground coordination
- New airport design and operation models
 - Intelligent runways and taxiways
 - Simultaneous landings and departures
- Smart non-towered airports
 - Autonomous sequencing and scheduling

Today's Challenges:

- Congested frequency spectrum limiting air traffic growth
- Voice-based air traffic control cannot support complex air traffic management concepts
- System provides insufficient security & integrity
- Communications capacity cannot support future air traffic management
- Coverage is lacking in remote and oceanic regions



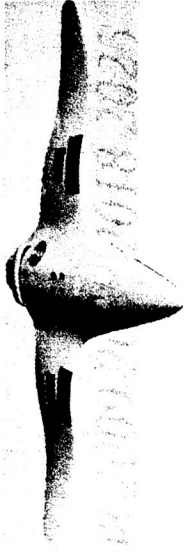
- Airborne Internet
- Secure networked communications
- Remote surveillance of all airspace
- Satellite communications and surveillance
 - Global surveillance and communications
 - Real-time cockpit weather and other hazard awareness
- Digital broadband communication



Aeronautics

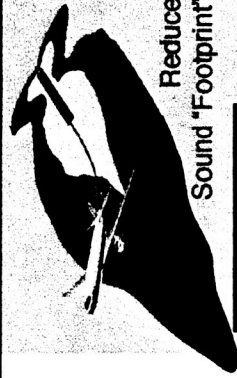
Blueprint

Revolutionary Vehicles



Today's Challenges:

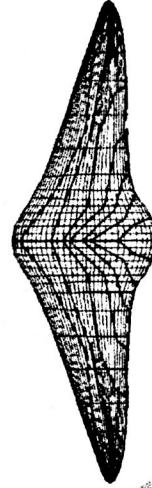
- **Reduce noise**
 - Eliminate airport restrictions
- **Lower emissions**
 - Reduce greenhouse gases
 - Improve local air quality
- **Improve safety**
 - Reduce the accident rate
- **Enhance capabilities—advance technology**
 - Autonomous operation
 - Supersonic overland flight
 - Runway independence



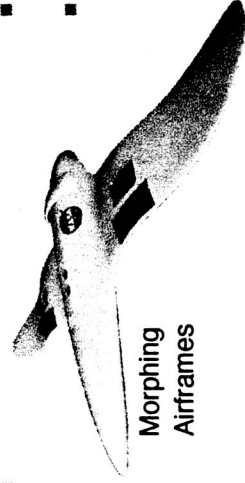
Reduce
Sound "Footprint"



Intelligent Propulsion System



Intelligent Sensors



Morphing
Airframes

- **Integrated airframe and propulsion systems**
- **Active flow and noise control**
- **Intelligent propulsion systems**
- **Fuel-efficient vehicles**
- **Robust flight control**
 - Reconfigurable control laws
- **Integrated vehicle health monitoring**
- **Automated decision aids**
- **Advanced vehicle concepts**



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Blueprint

Revolutionary Vehicles—Capabilities



Today's Challenges:

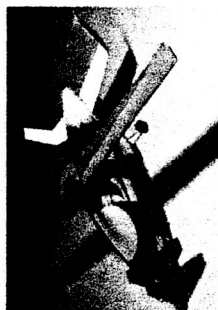
- Long-duration and large, long-haul transportation
- High-speed commercial transportation
- Quiet and efficient runway-independent aircraft
- Autonomous operations capability



- Months aloft at high-altitudes and long distances



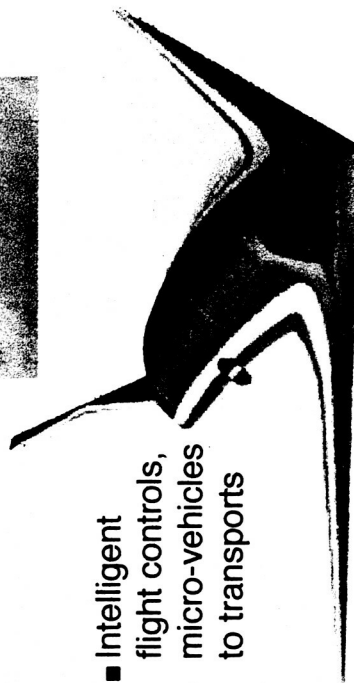
- Quiet, efficient, affordable supersonic flight



- Extremely short takeoff and landing—doorstep-to-doorstep



- Intelligent flight controls, micro-vehicles to transports





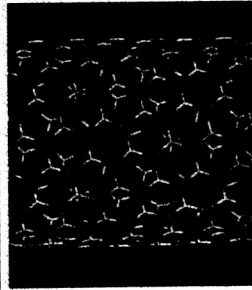
Aeronautics

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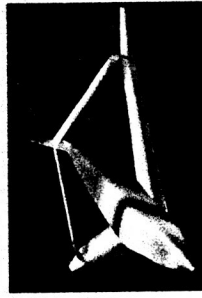
Revolutionary Vehicles—Technologies

Today's Challenges:

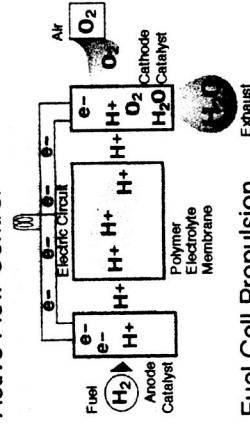
- Develop light, strong, and structurally efficient air vehicles.
- Improved aerodynamic efficiency.
- Design fuel-efficient, low-emission propulsion systems.
- Develop safe, fault-tolerant vehicle systems.



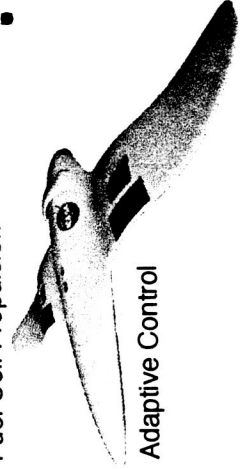
Nanotube



Active Flow Control



Fuel Cell Propulsion



Adaptive Control

- Nanostructures: 100 times stronger than steel at 1/6 the weight
- Active flow control
- Distributed propulsion
- Electric propulsion, advanced fuel cells, high-efficiency electric motors
- Integrated advanced control systems and information technology
- Central “nervous system” and adaptive vehicle control



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Revolutionary Vehicles—Noise



Today's Challenges:

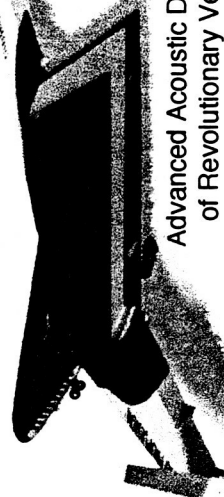
- Keep noise inside airport boundaries.
- Reduce the number of restrictions from the current 825 worldwide.
- Eliminate the need to sound-condition homes near airports.
- Revolutionize how citizens view airports.



Acoustic Properties of Landing Gear (CFD)



Acoustic "Footprint" of Chicago O'Hare



Advanced Acoustic Design
of Revolutionary Vehicles

- Eliminate noise by improving the design of engines, landing gear, and airframes.

- Understand the sources of noise.
- Integrate emerging materials, structures, and flow-control technologies.
- Develop revolutionary vehicle designs.

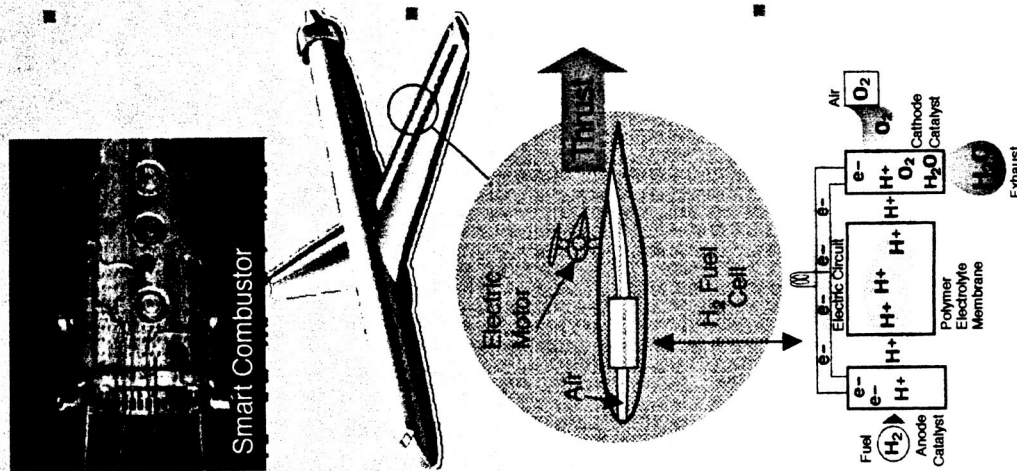
Noise Level	People Impacted
Baseline	= 620,000
-10 dB	= 55,000
-20 dB	= 0
Airport Boundary	

* DNL 55 is the EPA outdoor noise exposure level "requisite to protect the public health and welfare with an adequate margin of safety."

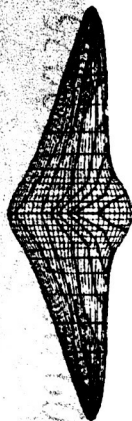


Today's Challenges:

- Improve local air quality; reduce NO_x
 - Projected to increase fourfold by 2050
- Reduce impact of aviation on global air quality; reduce CO_2
 - Projected to increase threefold by 2050



- **Intelligent combustors**
 - Sensors and actuators to control the combustion process
 - Smart materials
- **Increased fuel efficiency**
 - Ultra-lightweight and efficient aircraft
 - Dual-fan engines
 - Distributed propulsion
- **Electric propulsion**
 - Fuel cells
 - Global hydrogen generation and distribution



Today's Challenges:

- Provide all-weather visibility.
- Eliminate human error.
- Reduce component failures.
- Minimize the impact of weather hazards.
- Identify hidden risks.

Technology Solutions



- Synthetic vision provides visibility in all conditions
- "Refuse to crash" flight controls with digital terrain technology



- Human-centered designs



- Fault detection and reconfigurable systems
- Self-healing systems
- Precise knowledge of atmospheric conditions



- Advanced modeling of air traffic to identify and minimize risk



Aeronautics

Blueprint

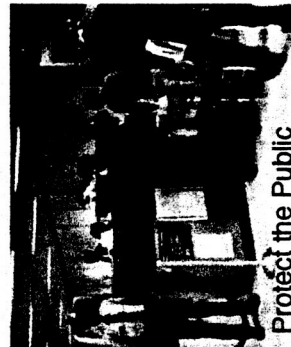
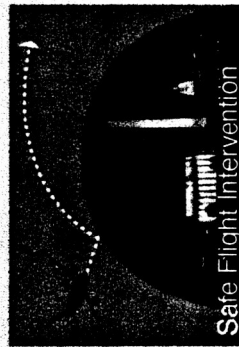
Aviation Security and Safety



Today's Challenges:

- Protect the public, passengers, and crew from danger or injury.
- Protect the airplane from threats.
- Prevent the aviation system from being used for malicious purposes.
- Develop solutions maximizing security of the Nation's aviation system while minimizing cost and unintentional consequences.

Technology Solutions



- Aircraft and systems hardening
- Flight operations with enhanced procedures and monitoring
- Air traffic surveillance and intervention
 - Onboard flight control
 - Ground control override
- Enhance security systems through application of information technology
 - Passenger threat assessment from reservation to boarding
 - Analysis of security data from 100's of airports and thousands of flights



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Aviation Security and Safety—Aircraft Hardening



Today's Challenges:

- Design systems to tolerate failures and damage.



- Blast-resistance structures, which can withstand damage and land safely

- Fault detection and reconfigurable avionics



- Self-healing systems
- Recoverable computers with Software-virus protection



- Network Intrusion prevention
- Secure communications
- Self-extinguishing fuel

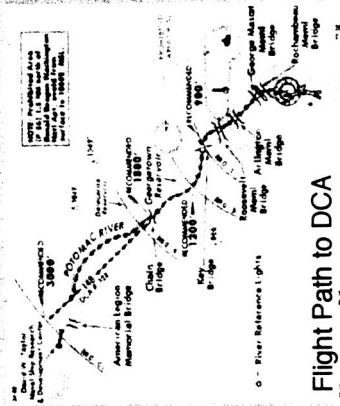
- Provide onboard network security and protection.

- Minimize fuel-fed fires



Today's Challenges:

- **Assure predictable approaches to metropolitan areas and around prohibited locations.**
- **Increase situation awareness of terrain and special airspace.**
- **Improve detection of deviations from the intended flight path.**



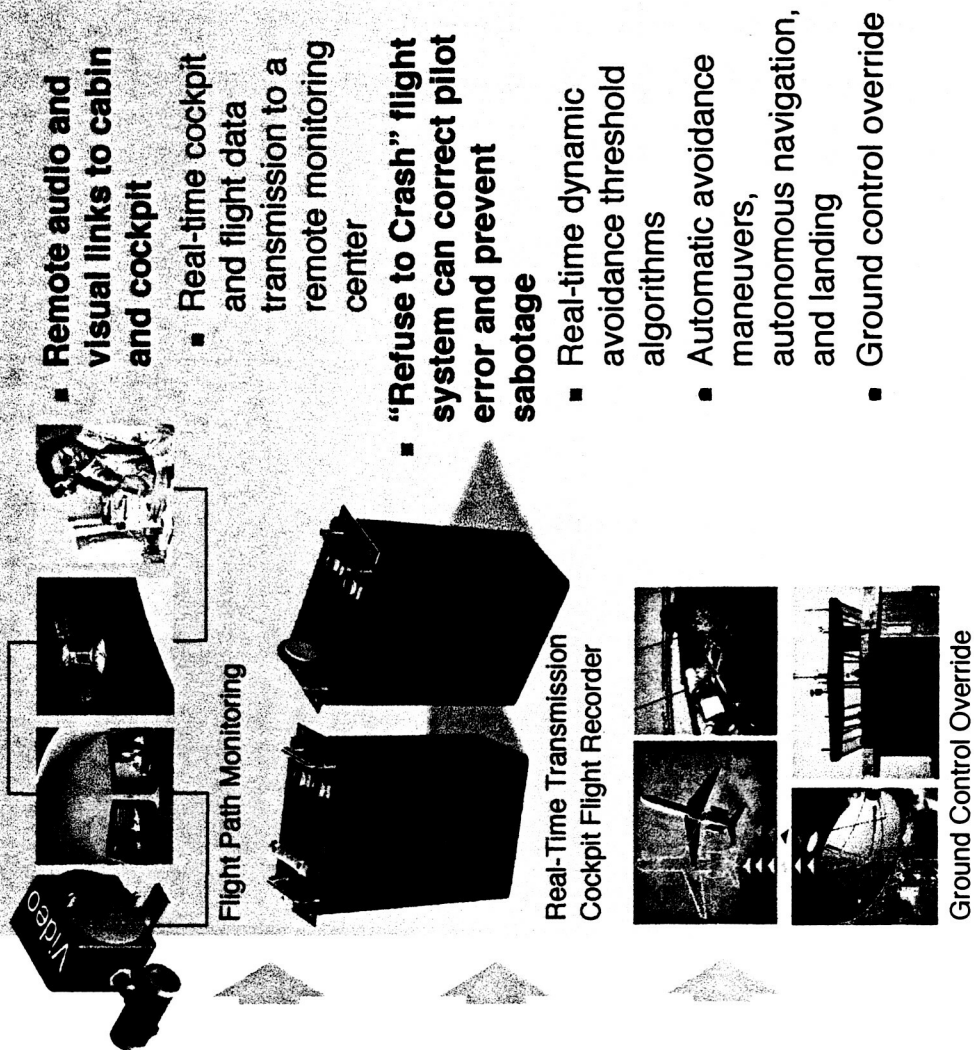
- **Precise flight path management**
 - Complex curved approaches
 - Four-dimensional approaches
- **Advanced modeling and evaluation of air traffic to identify and minimize risk**
 - "Intelligent" advisor for authorities
 - Simulate scenarios for training and mitigation strategy development
- **Remote monitoring of flight path conformance**
 - Notification of deviations
 - Rapid intervention strategy



Today's Challenges:

- Rapid detection of any state of duress on an airborne aircraft
 - Terrorist on board
 - Hazardous materials or other on-board threats
- Prevent intentional, destructive pilot-controlled flight.
- Prevent hazardous flight from non-malicious pilot actions.

Technology Solutions:





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Aviation Security and Safety—Information
Technology



Today's Challenges:

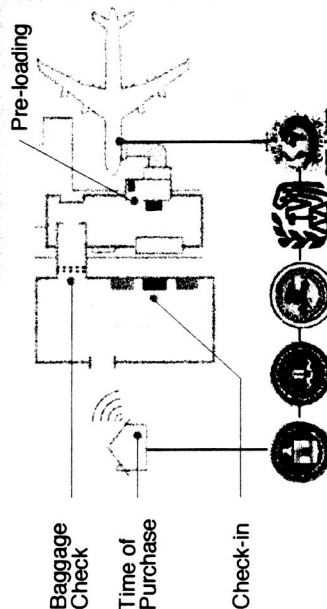
- Rapid pre-departure passenger screening and threat assessment
- Identify trends in system security status



Threat Assessment

Technology Solutions

- Real-time passenger threat assessment from reservation to boarding
 - Intelligent searches of distributed databases
 - Biometric identification
 - Context-sensitive threat evaluation
- Aviation Security Reporting System
 - Anonymous submission of security incidents
 - Data Mining to identify trends of concern and initiate preventative action



CIA FBI INS IRS Interpol

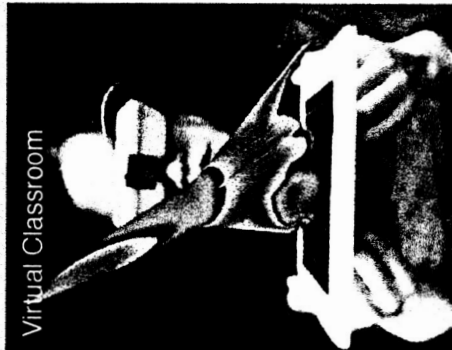
National Information System for
Transportation Security



State-of-the-Art Educated Workforce

Today's Challenges:

- Raise the interest in science and engineering in elementary, middle, and high schools.
- Prepare future graduates for a world of rapid technological change, complex systems, and advancements around the world.
- Maintain the high-tech workforce on par with the continuously advancing state of technology.



- Foster Interest and excitement in aerospace—establish an exciting vision for aeronautics
- Stimulate curriculum change and virtual and collaborative learning environments that will enhance educational relevance and scope
- Create life-long learning system that links classrooms to laboratories and on-the-job experiences



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Educated Workforce—Accomplishing the
Enterprise Mission



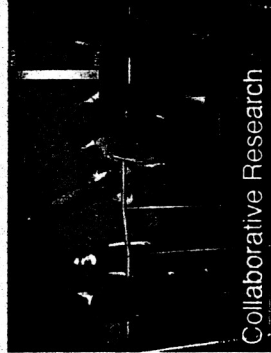
Today's Challenges:

- Adjust to the rapid loss of senior scientists and engineers (baby boomer demographics and reduced interest)
- Ensure seamless access to specialized talents and geographically dispersed teams.
- Keep pace with the rapid change of technology.
- Fill-in the knowledge gaps of aerospace research and technology to support major advances for the next generation of aerospace products.



- Develop long-term partnerships between government, universities, and industry research entities

- Create virtual collaborative research laboratories working on multi-discipline projects



- Workplace virtual classrooms support life-long and advanced distributed learning
- Adaptive learning computer systems for access to global scientific and technology knowledge

Summary and Actions



Aeronautics

Blueprint

Summary

- Driven by technology advances, aviation has progressed remarkably over the past century.
- Today's air transport system is facing severe constraints on further growth and service to the Nation.
- New technologies and operational concepts, nearly in hand and in early development, offer the potential to far surpass those constraints and create a new level of performance and capability in aviation.
- NASA, academia, FAA, DOT, DoD, and industry are needed in order to realize this vision.
- Now is the time to aggressively pursue
 - advanced concepts for the airspace system;
 - revolutionary vehicles with significantly greater performance;
 - new paradigms for safety and security; and
 - the development of a capable, flexible workforce of the future.
- The cost of inaction is gridlock, constrained mobility, unrealized economic growth, and loss of U.S. aviation leadership.



Aeronautics

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NASA's First Steps to Achieve the Vision

- Structure investments and performance metrics based on systems analysis and public good.
- Evaluate, realign, and strengthen our workforce, facilities, partnerships, and ways of doing business.
- Renew our focus on innovation in engineering tools and capabilities for complex aerospace systems:
 - Act in partnership with industry
 - Act as a catalyst for the future workforce
- Restructure approach and portfolio for long-term research:
 - New national technology competencies
 - New, expanded approach to University Research Center partnerships
- Continue to strengthen interagency partnerships to meet national needs.
- NASA is embarking on technological changes for the 21st century.

The following overview of the

NASA Aerospace Technology Enterprise

Strategic Plan Introduction

may be found on the

world wide web at

<http://www.aerospace.nasa.gov/library/stratplan/intro.pdf>



Aerospace
Technology
Enterprise

Strategic Plan

Advance Space Transportation

Revolutionize Aviation

Pioneer Technology Innovation

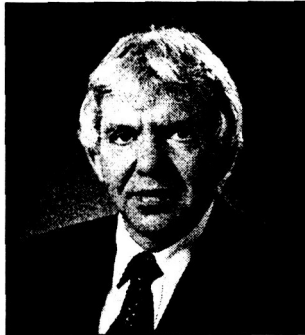
Commercialize Technology

THE AEROSPACE TECHNOLOGY ENTERPRISE IS AN INVESTMENT IN AMERICA'S FUTURE.

The future we see includes:

- A safer, cleaner world, in which the safety of air transportation is unquestioned and aircraft noise and emissions are dramatically reduced.
- A more open world, in which people everywhere can quickly, easily, and inexpensively travel wherever their lives lead them.
- An expanded world, in which space is fully opened for all human endeavor
- A world of opportunity, in which technologies developed through NASA's R&D investment are fully exploited for the benefit of our society.

Letter from the Associate Administrator



This strategic plan represents our blueprint for a new era in aerospace for the United States. The plan sustains the commitment of NASA's Aerospace Technology Enterprise to the Nation with technologies that contribute to the public good, quality of life, and national security. The challenges and opportunities facing the Nation in commercial transportation for both air and space, and for civil space and exploration, provide the imperative for our Goals and Objectives. A revitalized commitment to innovation in technology and engineering practices provides the vision and means to achieve these Goals and Objectives.

This is an exciting time for aerospace technology. New expertise and research directions in areas such as information technology, nano-technology, and biologically-inspired technologies are all creating new possibilities. Coupled with our traditional aerospace engineering competencies such as aerodynamics, guidance and controls, and materials and structures, these new competencies will enable levels of performance and functionality that were unimaginable only a decade ago. We can now envision a wing that "morphs" its shape, a structure that heals itself, and a control system that senses and controls its own operations down to the molecular level. This is truly one of those unique periods of discovery, during which we can match our traditional strengths with emerging capabilities to produce a new era in aerospace.

This plan and the supporting programs of the Enterprise are both exciting and important. We are continually looking for ways to increase our contributions to technological advancements in flight and our effectiveness in meeting the challenges that come our way. I invite you—our partners, customers, users, and stakeholders—to join with us in creating the future and turning goals into reality.

A handwritten signature in dark ink, appearing to read 'Samuel L. Venneri'.

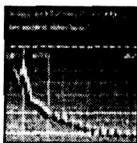
Samuel L. Venneri
April 2001



Goal One:

Revolutionize Aviation

Enable a safe, environmentally-friendly expansion of aviation
(Baseline: 1997)



Increase Safety:

Make a safe air transportation system even safer

Objective 1: Reduce aviation's fatal accident rate by a factor of 5 within 10 years, and by a factor of 10 within 25 years.



Reduce Emissions:

Protect local air quality and our global climate

Objective 2: Reduce NO_x emissions of future aircraft by 70 percent within 10 years, and by 80 percent within 25 years (using the 1996 ICAO Standard for NO_x as the baseline). Reduce CO₂ emissions of future aircraft by 25 percent and by 50 percent in the same timeframes (using 1997 subsonic aircraft technology as the baseline).



Reduce Noise:

Reduce aircraft noise to benefit airport neighbors, the aviation industry, and travelers

Objective 3: Reduce the perceived noise levels of future aircraft by a factor of 2 (10 decibels) within 10 years and by a factor of 4 (20 decibels) within 25 years, using 1997 subsonic aircraft technology as the baseline.



Increase Capacity:

Enable the movement of more air passengers with fewer delays

Objective 4: Double the capacity of the aviation system within 10 years and triple it within 25 years, based on 1997 levels.



Increase Mobility:

Enable people to travel faster and farther, anywhere, anytime.

Objective 5: Reduce inter-city door-to-door transportation time by half in 10 years and by two-thirds in 25 years, and reduce long-haul transcontinental travel time by half within 25 years.



Goal Two:

Advance Space Transportation

Create a safe, affordable highway through the air and into space.
(Baseline: 2000)



Mission Safety:

Radically improve the safety and reliability of space launch systems

Objective 6: Reduce the incidence of crew loss for a second generation Reusable Launch Vehicle (RLV) to 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1 million missions (an additional factor of 100) for a third generation RLV by 2025.



Mission Affordability:

Create an affordable highway to space

Objective 7: Reduce the cost of delivering a payload to Low-Earth Orbit (LEO) to \$1000 per pound (a factor of 10) by 2010 and to \$100 per pound (an additional factor of 10) by 2025. Reduce the cost of interorbital transfer by a factor of 10 within 15 years and by an additional factor of 10 by 2025.



Mission Reach:

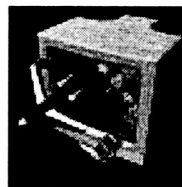
Extend our reach in space with faster travel

Objective 8: Reduce the time for planetary missions by a factor of 2 by 2015 and by a factor of 10 by 2025.

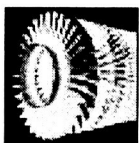
Goals and Objectives



Goal Three:
Pioneer Technology Innovation
 Enable a revolution in aerospace Systems.



Goal Four:
Commercialize Technology
 Extend the commercial application of NASA technology for economic benefit and improved quality of life.



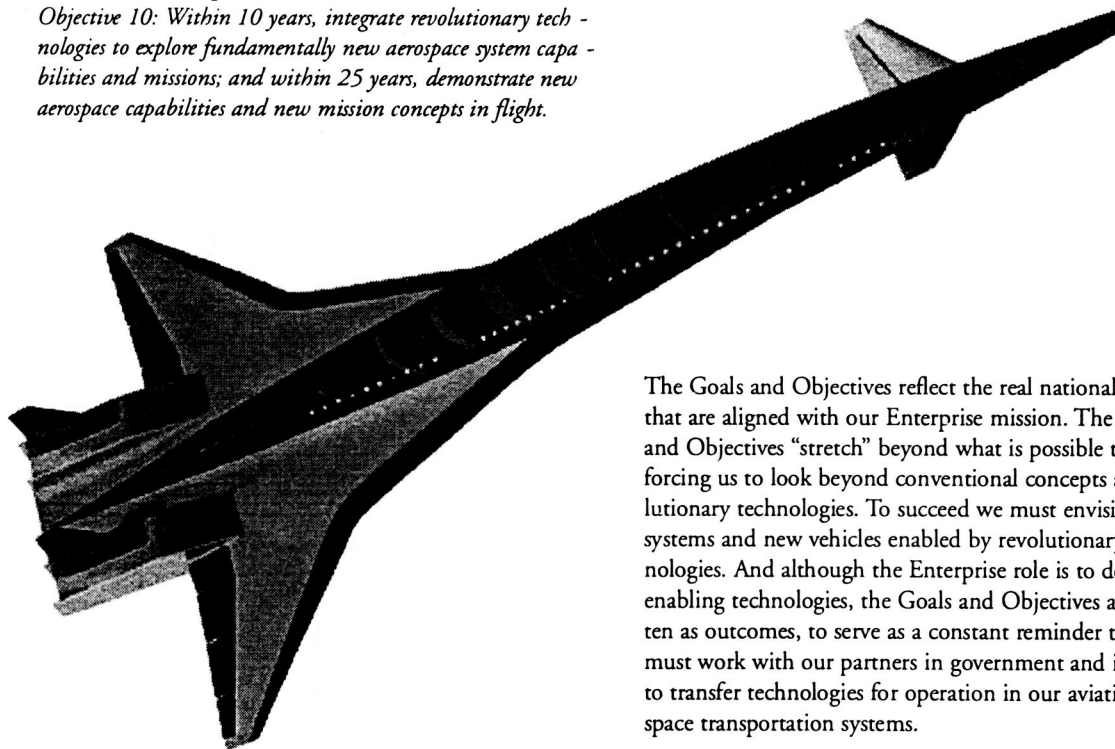
Engineering Innovation:
 Develop advanced engineering tools, processes, and culture to enable rapid, high-confidence, and cost-efficient design of revolutionary systems

Objective 9: Within 10 years, demonstrate advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications; and within 25 years, demonstrate an integrated, high-confidence engineering environment that fully simulates advanced aerospace systems, their environments, and their missions.



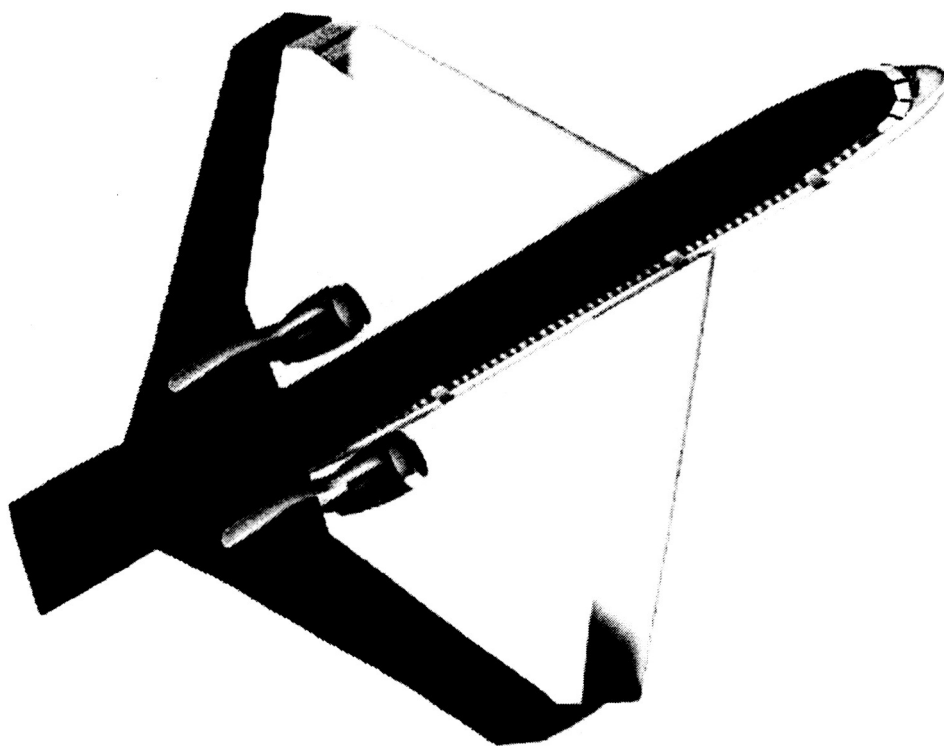
Technology Innovation:
 Develop revolutionary technologies and technology solutions to enable fundamentally new aerospace system capabilities and missions

Objective 10: Within 10 years, integrate revolutionary technologies to explore fundamentally new aerospace system capabilities and missions; and within 25 years, demonstrate new aerospace capabilities and new mission concepts in flight.



The Goals and Objectives reflect the real national needs that are aligned with our Enterprise mission. The Goals and Objectives "stretch" beyond what is possible today, forcing us to look beyond conventional concepts and evolutionary technologies. To succeed we must envision new systems and new vehicles enabled by revolutionary technologies. And although the Enterprise role is to develop enabling technologies, the Goals and Objectives are written as outcomes, to serve as a constant reminder that we must work with our partners in government and industry to transfer technologies for operation in our aviation and space transportation systems.

NASA's charter is to pioneer advanced technologies that will meet the challenges facing air and space transportation, to maintain U.S. national security and preeminence in aerospace technology, and to extend the benefit of our innovations throughout our society.



Summary of Issues

- Both the economy and our quality of life depend on a safe, environmentally-friendly air transportation system that continues to meet the demand for rapid, reliable, and affordable movement of people and goods.
- To fully benefit from the revolution in communication and information technology, we also need a revolution in mobility.
- To open the space frontier to new levels of exploration and commercial endeavor, we must reduce cost and increase the reliability and safety of space transportation.

Strategic Basis

Strategic Basis for the Aerospace Technology Enterprise Goals and Objectives

A modern air and space transportation system is fundamental to our national economy, quality of life, and the security of the United States. For 75 years, a strong base for aerospace technology research and development has provided enormous contributions to this system; contributions that have fostered the economic growth of our Nation and provided unprecedented mobility for U.S. citizens. In the past 30 years we have reduced aircraft noise by a factor of 10, cut fuel consumption in half, and maintained a notably low accident rate despite a threefold increase in flight operations.

Although major technical advances have made our Nation's air and space transportation system the largest and best of its kind, the future holds critical challenges to its continued growth and performance. Meeting these challenges with effective solutions will require a sustained focus on long-term advances in science and technology.

Because the U.S. air and space transportation system serves both critical national security needs and the public good, ensuring the continued health and preeminence of that system is a key issue for the future of this Nation.

NASA is the Nation's leading government agency for providing technological leadership and advancements for the Nation's aerospace industry and the traveling public. To address the major needs for our future air and space transportation systems, NASA's Aerospace Technology Enterprise has formulated 10- and 25-year objectives in ten areas. Achieving these objectives would not only create a future system characterized by many new capabilities, but would also continue to contribute toward strengthening national security and improving the quality of life for all Americans. In addition to its role in advancing air and space transportation, the Enterprise has a role in developing basic technology for a broad range of space applications, such as aerospace communications, power and propulsion systems, microdevices and instruments, information technology, nano-technology, and biotechnology. These advances will allow space missions to expand our knowledge of Earth and the universe.

Importance of Air and Space Transportation to the U.S. Economy

Air travel is the preferred mode for long-distance travel, accounting for 50 percent of all personal travel farther than 1000 miles and 75 percent of travel farther than 2000 miles.

For years, the amount of air cargo has been growing at a rate of 10 percent or more annually. Its growth is driven by increases in global commerce and a greater volume of high value, time sensitive cargo. In 1998, the total economic output attributable to aviation-related activity was \$259 billion, or about 3 percent of the Nation's \$8.67 trillion Gross Domestic Product (GDP). For aircraft alone, the projected market for the years 1999 to 2008 is in excess of \$800 billion. Worldwide, the passenger and cargo air transportation markets together are growing at a faster rate than that of global GDP.

Historically, transportation and communication have always been integrally linked. Today, tourism, e-commerce, and other factors such as economic growth and changing demographics are fueling demand for access to high-speed, highly distributed transportation systems. The transportation system for this new interconnected world must feature greater mobility, measured in terms of increased flexibility, greater convenience, shorter door-to-door trip times, and lower real costs.

Growth in the space sector is fueled by rapid acceptance of satellite and broadband services, a result of worldwide demand for various mobile services and the critical nature of business and consumer data. The media, internet, entertainment, and telecommunications communities have embraced satellites and made them an integral part of their overall infrastructure.¹ Fueled by non-government applications, industry revenues worldwide reached \$97.6 billion in 1998 and, although revenues fell to \$87 billion in 1999², experts expect continued steady growth.

For the U.S. commercial space launch industry, however, 1998 and 1999 were disappointing years, due to a string of failures that restricted the launch rate and slowed the development of new vehicles.

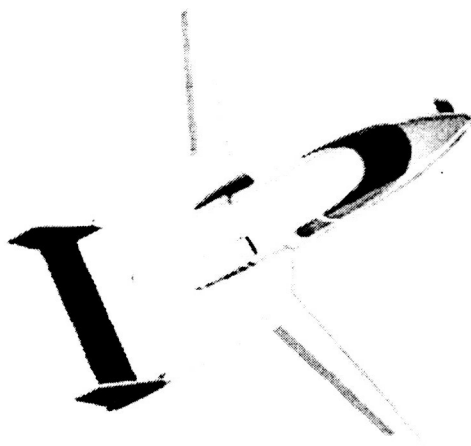
Increasingly, "commercial space" companies are smaller start-up companies (versus established aerospace companies) and are faced with a fundamental need for faster and less expensive development and delivery of systems. A number of entrepreneurial ventures have announced plans for commercial launch vehicles in hopes of capturing some of the strong market for launch services of commercial satellites. Satellite systems, projected to account for approximately two thirds of the demand for launches, are beginning to demonstrate how well they fit into the global information infrastructure.

As we begin the 21st century, our government's space program seeks to forge a "Highway to Space" that will enable its citizens to travel, work and live in space as a matter of routine. NASA research will make it possible for industry and the private sector to make space transportation economical. This in turn will create enormous opportunities for commercial endeavors, new services, scientific and medical research, and other uses not yet imagined.

Limits to Growth

"Aerospace has for a number of years been among the most dynamic and expansive of U.S. industries. In 1998, domestic and international sales by U.S. aerospace companies were about \$140 billion, or about 3% of all U.S. industrial manufacturing activity. New orders for the year totaled about \$124 billion, and the backlog of orders at year-end amounted to \$204 billion. The industry currently employs approximately 860 thousand Americans. The industry's export performance has been most remarkable, particularly when compared to that of other U.S. industries. In 1998, exports reached \$64 billion, while imports of aerospace products amounted to about \$23 billion. This means the U.S. trade surplus in aerospace products was roughly \$41 billion, a continuation of a long-term trend of positive trade balances."³

Because of this and other impacts on the U.S. economy, aerospace systems are under heavy pressure to keep pace with rising demands. Unfortunately, aviation's infrastructure is unlikely to expand in the foreseeable future in response to those demands, because of the noise and air quality impact on communities near airports. Therefore, rising demands must be accommodated by the airports and facilities that already exist.



¹ Source: PR Newswire, June 19, 2000, "Worldwide Revenues Soar to \$87 Billion in 1999 to Increase by More Than 90 Percent Over Next Five Years."

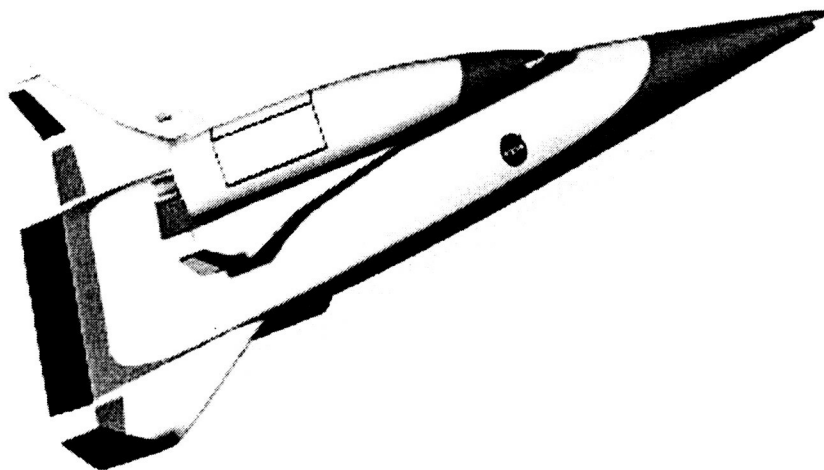
² Source: 1999 State of the Space Industry, 2000 State of the Space Industry, International Space Business Council.

³ Source: Testimony by Joel L. Johnson, Vice President, International Aerospace Industries Association, to the House of Representatives Committee on Government Reform, June 29, 1999, Offsets Related to Military Sales.

The challenges for aviation are to improve safety and security, enable more flexible and efficient air traffic management, and eliminate the negative environmental impact of aircraft operations. Compounding these challenges is the reduced drive by the military for aerospace technology, due to the decline in military aerospace research and development (R&D) and procurement. In past decades, the motivation for advances in aerospace technologies was dominated by military needs: the partnership among NASA, Department of Defense (DoD), and industry rapidly advanced, matured, and integrated aerospace technologies; then these technologies were appropriated for commercial use, with great success.⁴

The main challenges for the space industry continue to be reliability and cost. Space launch is prohibitively expensive and risky for all but missions of national importance and the most lucrative commercial efforts, such as worldwide broadcasting satellites. Whether doing business in Earth orbit or exploring distant worlds, the first few hundred kilometers of the "Highway to Space" are the toughest part of the journey. Fully half the energy needed to go to the farthest planets in our solar system is devoted to escaping Earth's gravity and getting into low earth orbit. U.S. commercial launch vehicles are based largely on decades-old technology, and foreign companies now control the majority of the launch business once dominated by the United States.

The space industry is changing dramatically as it transitions from government-driven needs to market-driven growth. However, this industry is less mature than the aviation industry and the technologies are more complex. Increasing safety and reliability and reducing the cost of space transportation will expand its market and increase this industry's role in the economies of many nations.



⁴ Examples of technology transfer from the military to the commercial sector: The turbine engine introduced on the B-707 was originally designed for military aircraft. The Pratt & Whitney J-57 and General Electric J-79 engines were also originally developed for military use. The B-707 airframe was developed jointly with a military tanker program. The DC-10, L-1011, and B-747 were developed based on research into wide-bodied aircraft, while competing for what became the C-5A military transport contract. Revolutionary fly-by-wire flight controls that were developed and first adopted for U.S. military aircraft are now incorporated into Boeing's newest commercial aircraft.

The Role of Technology

Technology has a significant role in meeting these challenges. Advanced physics-based modeling, simulation, new materials and structural concepts, and other technologies will enable quieter, more efficient aircraft and more robust and affordable spacecraft. A new information network for a modernized National Airspace System (NAS) will allow greater flight efficiency and capacity. As the space transportation system grows, it will be linked increasingly with the aviation system. In the future, a single aerospace system will serve both air and space transportation.

Aerospace has always been a leader in applying advanced technologies. New technology will drive the next wave of innovation, enabling missions to be performed in completely new ways and creating missions that were never before possible.
















Technologies that enable simplified space transportation operations, robust design and operating margins, and near complete reuse of hardware have the potential to reduce costs dramatically. Equally important are new propulsion technologies that will enable new in-space operations, such as economical travel between low-earth orbit and geo-stationary orbits and faster travel to other planets and—ultimately—the stars. Safe, low-cost space transportation will make space commercially accessible for both passenger and cargo operations. It will also allow the continued expansion of human and robotic exploration throughout our solar system.

The Role of the Government

Problems with the environment and other elements of the aviation infrastructure, such as air system capacity and air traffic control, are not easily addressed by the private sector. The resulting delays and the noise and emissions pollution are not even priced in the market place.

Economists term these problems "externalities" because, unlike other costs, no market participant pays for them directly. As a result, the private sector has inadequate incentives for addressing the very real problems that aviation imposes. Developing, maintaining, and regulating national transportation infrastructures, as well as other significant areas such as national security, are the responsibilities of the government.

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The government also has responsibility for maintaining a strong technology base for air and space transportation, to ensure the competitiveness of the U.S. economy. This is a multi-faceted issue that the government can affect as a direct or indirect result of policy. "Key factors that will influence future global [economic] growth are rates of productivity, technological innovation, international competition, improvements in aviation infrastructure, levels of defense spending, and support by governments for their aerospace industries."⁵

The aerospace industry remains critically dependent on technology. Even as NASA's priorities change to meet the changing needs of society, it still pursues long-term efforts in aerospace science and technology; efforts that would not be made otherwise, either by the private sector or by other government agencies.

NASA continues to play a unique role by connecting and leveraging the aerospace research infrastructure in both the private and public sectors. In this regard, partnerships remain a critical element in disseminating and applying NASA-developed technologies.

There is a strong relationship between leadership in aerospace technology and the economic, social, and political well-being of this Nation. Given this relationship, the Nation's continued investment in aerospace technology research remains critical, and NASA's role remains clear and vital.

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⁵ U.S. Industry & Trade Outlook 2000, International Trade Administration of the U.S. Department of Commerce, and The McGraw-Hill Companies, Inc., p. 21-1.